EXTRACT FROM THE UNITED STATES ARMY X-RAY MANUAL

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EXTRACT FROM THE

UNITED STATES ARMY

X-RAY MANUAL

AUTHORIZED BY THE SURGEON-GENERAL OF THE ARMY

Prepared under the Direction of the Division of Roentgenology

[219 ILLUSTRATIONS]

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X-RAY PHYSICS

Introduction.—The following brief notes on the physical aspects of the apparatus likely to be used in military roentgenology have been written with the hope that their study might enable the roentgenologist to prepare for service in less time and be better able to utilize the apparatus with which he is compelled to work. With the belief that brief reasons as to why things are done are good guides in operation, rather more explanation of fundamental principles has been given than is usually included.

X-Rays.—The roentgen or x-rays are produced by an electric current in a glass-walled vacuum tube. Such a current is due to the projection of minute electric particles (electrons) from one metal terminal, the cathode, to another metal terminal, the anode or target. The x-rays originate at the point of impact of the electrons on the target and travel out from their origin in all directions except where dense material obstructs or prevents their passage. When passing through bodies made up of various parts differing in density, some of the rays that enter the denser portions are permanently cut out and a new distribution of intensity in the beam results.

The presence of x-rays must be determined by some of

the effects they produce when acting on material bodies. These actions are:

1. Effect on the emulsion of a photographic plate.
2. Excitation of light in certain crystals (fluorescence).
3. Rendering gases conducting to electricity (ionization).
4. Stimulating or destructive action on living cells (biological action).

The first, second, and fourth of these are of fundamental value in the medical and surgical uses of the rays. The third has been very useful in the study of the radiation.

These rays do not excite vision on reaching the retina of the eye, but are capable of originating light in certain crystals. A uniform beam, falling on a piece of cardboard covered with such crystals, would cause uniform illumination. If regions of unequal material density have been traversed by the beam before reaching the screen (fluoroscope), such dense portions will show as areas of lesser brightness or, as we say, will cast shadows. In the same way, a photographic plate or film sufficiently acted upon by such rays will, on development, give areas of unequal blackening, marking out the *projections* of volumes in the body whose densities differ from those surrounding them. On the fluoroscopic screen, dense bodies show as *dark* areas; in a photographic negative, they show as *light* areas.

It has been shown by various investigations that x-rays are identical in their nature with light and electric waves, except that their wave lengths are very much less than even the shortest light waves. On account of this extremely short wave length, the effect of matter upon their propagation is quite different from that in the case of longer waves. Such short waves are only produced by a change in the velocity of electrons taking place in intervals

of time too short to be easily conceived. The gamma rays of radium, etc., are simply rays due to the sudden *starting* out of electrons by atomic breakdown. They may be shorter or longer than the x-rays we use in fluoroscopy or in radiography.

The term ray is used to designate two distinct types of phenomena. One, a projection of small particles by atomic disintegration, as beta and alpha rays. The other refers to the transfer of physical effects by the agency of wave motion. In this class we have light, gamma and x-rays.

It may be also noted here that gamma rays are of the same physical nature as x-rays, but some gamma rays are of shorter wave length than the x-rays we are able to produce at the present time.

The following general properties of this radiation should be understood in order to facilitate its intelligent application.

Paths.—These rays travel in straight lines into, through, and out of material bodies, except where the atoms themselves cause scattering. They *cannot be directed* by mirrors or lenses for purposes of optical focus or concentration, as is done with light. The slight amount of regular reflection by the uniformly spaced atoms in crystals is too small to be of any importance to the roentgenologist.

Velocity.—The rays travel out from the target at the same velocity as light or electric waves.

Energy.—The actual energy involved in an x-ray beam is small compared with that expended in getting it started; only a few parts in a thousand of the energy supplied is converted into x-rays.

Scattering.—X-rays are scattered in passing through matter exactly as light is scattered in turbid water, fog,

paraffin, etc. Only a part of a beam is thus scattered, the remainder passing straight through or being absorbed. Scattering confuses shadows on screen or plate in a very troublesome way.

Passage Through Matter.—When rays pass through material, the substance is called transparent to the radiation. If little or no radiation gets through, we say the material is opaque to this radiation. The terms transparent and opaque refer to the action of the material with reference to a specific type of radiation. If one arranges a variety of substances of like thickness in the order of *increasing* density, their *opacity* to x-rays will be nearly in the same order. But this will vary somewhat according to the quality of the x-ray beam considered. That portion of the incident radiation neither transmitted nor scattered is changed into heat or, as we say, absorbed in the material. We then say that absorbing power increases with the density of the absorber. This absorbing power is best expressed as the fraction of the rays absorbed by a definite thickness of material. Thus, if 1 cm. of water should reduce a particular radiation so that the emerging beam is half as effective as the entering one, we might say this radiation has a *half value* layer of 1 cm. of water. Two centimeters of water would transmit only 25 per cent of the incident beam or that reaching the surface proximal to the tube.

The quality of short wave length and high penetration can be secured only by means of high voltage operation. (See penetration, p. 46.)

Electrons.—The modern concept of atoms involves the idea of their general electrical constitution. From any atom there may be abstracted one or more small negative charges, all precisely alike, whose properties are in no wise

dependent on the atom from which they come, and all are quite capable of existence by themselves without the presence of the remainder of the atom. These little bodies have been variously named as corpuscles, cathode rays, beta rays, electric-ions, etc. The common designation of electron is derived from the latter. An electron is able to respond to electric force and to acquire velocity under such force action. When in motion, they show all the characteristics of an electric current.

The main physical features of electrons are:

1. Their fixed and definite negative charge.
2. Their extremely small mass and volume.
3. The extreme speed they may acquire.

Production of X-Rays.—Roentgen or x-rays originate in any region where the velocity of electrons is suddenly changed. In the radio-active breakdown of atoms, this change is a sudden *acquisition* of velocity, and the gamma rays are produced. In x-ray tubes, the high-speed electron is stopped in its flight by the interposition of a target metal of high atomic weight placed in its path, and x-rays result from a *loss* of velocity.

The problem of x-ray production for our purpose, then, resolves itself into four parts.

1. The separation of electrons from atoms.
2. Giving them high speed.
3. Concentrating them on a small area.
4. Stopping them with sufficient suddenness.

The first of these is accomplished in one of two ways. In the tubes containing a *small amount* of gas, electrons are secured in part by high electric field, but to a much greater extent by the disruption of atoms due to the moving electrons and by the x-rays themselves. In the more

recent hot cathode tube (Coolidge), electrons are set free from the atoms in a tungsten wire by the action of heat. In the former, the number of available electrons is rather hard to control, while in the hot cathode tube this offers no difficulty.

In order to secure high speed (one-half to one-third the velocity of light) a high voltage must be available, and the electrons must all be urged toward the same small area in order to get sharp shadows. The concentration on the target is secured by proper design of the electrodes and their proper position in the tube. In all cases the path to be followed must be quite free of gas in order to avoid obstruction.

The choice of metal as a barrier is of great importance, and only a few elements satisfy the conditions. Every fast-moving electron has some mechanical energy and this goes mainly into heat by impact; there results a great rise in temperature at the point of electron concentration. As radiographs and fluoroscopic images are purely shadow effects, a source of radiation starting from a point is very desirable. This high concentration of heat will melt any target material at high power operation. Only metals of high melting points can be utilized, such as platinum, tungsten, osmium, and iridium. Of these the first two are in common use, the tungsten to a great extent during recent years. High atomic weight is also desirable, and fortunately this goes with high melting points in the above metals.

General Instructions and Precautions.—1. *Excessive* exposure to x-rays results in serious injury to the skin. Such injury does not manifest itself at once but may develop some weeks later. To a degree, the action is cumulative, so that a single dose, in itself too small for

injury, may, when frequently repeated, be harmful. Read carefully the notes as to protection, page 194. While it is unwise to be over timid, it is much easier to prevent an injury than to cure it.

2. X-ray apparatus is expensive, and not only is it costly in money to repair damage, but even more important is loss of service from breakdown. Do not try to see how much current you can pass through a tube or how long a spark the transformer will give. Do not imagine that a tungsten target cannot be melted; it can, and very quickly.

3. Acquire the habit of observing whether high tension wires are sufficiently far from patient, assistants, etc., *before* you close the operating switch.

4. Make all tests of tubes, etc., on low power, when possible, and do not make unnecessary speed your ambition. When through work, throw all controls to low power.

5. Never test out a tube when the patient is in position.

6. Always see that current is passing through the filament of a Coolidge tube before closing the main transformer switch.

7. Do not imagine you can make plates of thick parts on very low spark gaps. It cannot be done, but you may get some very unfortunate experience trying it.

8. Remember that any current that passes across the spark gap or leaks from one line to the other along walls, etc., does not help to produce x-rays, although it may increase your milliammeter reading.

9. Try to develop a definite order and sequence in the various details of any examination. It will save time and prevent errors.

10. The only safe time to label a plate or film for identification is at the time of exposure.

11. Don't imagine that so and so's good plates are due to the particular machine he is using; and don't chase off after every new exposure "technique" you hear about. The fact that some individuals advocate one after another is ample evidence of their uselessness.

Electrical Terms.—Certain terms are used so frequently in all discussion of electrical matters that they are introduced at this point for convenience in reference.

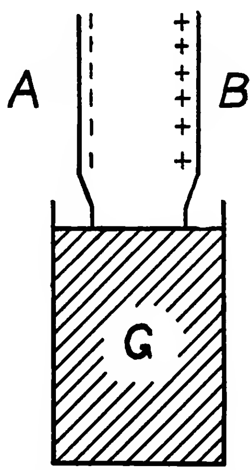

FIG. 1. Generator on open circuit.

Charges.—When any physical or chemical action breaks down the connection between an electron and the remainder of the atom, the electron constitutes the elementary particle of negative electricity. All negative charges are simply countless numbers of electrons kept away from the positive portions of the atoms from which they were separated.

Generators.—Generators do not create electricity. They take electrons and positive atomic remainders apart and push them in opposite directions against their natural tendency to keep and come together. Thus, if *G*, Fig. 1, represents a generator, *A* and *B* metallic plates connected to its terminals, *A* is covered with electrons and *B* with enough positive to neutralize the negative on *A*. If we call *e* the negative charge of one electron, and *Q* the total charge on *A*, *N* the number of electrons, then *Q* equals *Ne*, where *N* is an incredibly large number in most cases.

Voltage.—Electric charges separated as shown in Fig. 1, show: (1) a mechanical pull on the bodies A and B, (2) a decided tendency to pass between A and B.

A voltmeter does *not* measure electricity but something like a pressure or strain trying to pass a charge between two regions.

The Volt.—The volt is the unit in which the tendency of charge to move from one place to another is measured. The electrical tension between the terminals of a special cell (Weston or Cadmium cell) is taken by legal definition as 1.019 volts.

Current.—When proper external connections are made to the terminals of a generator there results a transfer of charge. If we could count the number of electrons passing on to A per second, say n, we would call ne the current passing through G. An electric current may then be regarded as a measure of the number of electrons passing per second. It must be observed that after A and B are charged as highly as is possible for the particular generator, there will be no further current, but the voltage is present. *We may have voltage existing and no current, but never a current without some voltage.*

The Ampere.—The ampere is the unit of electric current. It is legally defined as the rate of transfer of electric charge which deposits silver from a special solution at the rate of .001118 grams per second. The unit electric charge is the coulomb. Five amperes, for example, will transfer 40 coulombs in 8 seconds.

Resistance.—It requires but little voltage to move a big supply of electrons through some materials, while with others a very great voltage will cause but little electron movement. The former are named conductors; the latter, insulators. Note carefully that the difference is one of

degree, and that perfect insulators do not exist so far as high applied voltage is concerned. Thus, dry, clean glass may be considered an insulator for moderate voltages, but may conduct to a considerable extent at high voltage. The objection offered to the passage of an electric current by any material included in a circuit is called its resistance.

The Ohm.—The unit of electrical resistance. Legally defined as the resistance of a uniform column of mercury 106.3 cm. long and one square millimeter section at 0° centigrade.

Power.—The ability of the electric current to do work is termed its power.

The Watt.—The watt is the unit of electrical power. It is the power of a current of 1 ampere in a region where it loses 1 volt. The product, amperes x volts lost = power in watts; 746 watts are equivalent to one mechanical horsepower, and 1 kilowatt is therefore equal to about 1⅓ horsepower.

Derived Units.—The units given above are not of convenient size in all cases, and some modifications are in common use. The terminal voltage on the tube is high, and it is often expressed in kilovolts (1 kilovolt equals 1000 volts). The current ordinarily used through x-ray tubes is small and is expressed in milliamperes (1 milliampere equals $\frac{1}{1000}$ ampere). The power used to operate electrical devices is generally expressed in kilowatts, when the number of watts is large (1 kilowatt equals 1000 watts). One kilowatt maintained for one hour is named a kilowatt-hour.

As applied in particular cases, a 4 kw., 110 volt generator, is a machine that delivers 4000 watts at full load and is designed to operate at 110 volts. The full load

current would be $\frac{4000}{110} = 36.3$ amperes. If a machine gives 50 *milliamperes* at 70 *kilovolts,* the power delivered is $\frac{50}{1000} \times 70 \times 1000 = 3500$ watts, or $3\frac{1}{2}$ kw.

Measuring Instruments.—The electrical measuring instruments that may concern the roentgenologist are the ammeter and the voltmeter for *low tension circuits,* the milliammeter, and the kilovoltmeter for *high tension circuits.* Most kilovoltmeters are of little real value as they vary with the secondary current. The milliammeter is a most valuable aid to the work. It is often designed for two

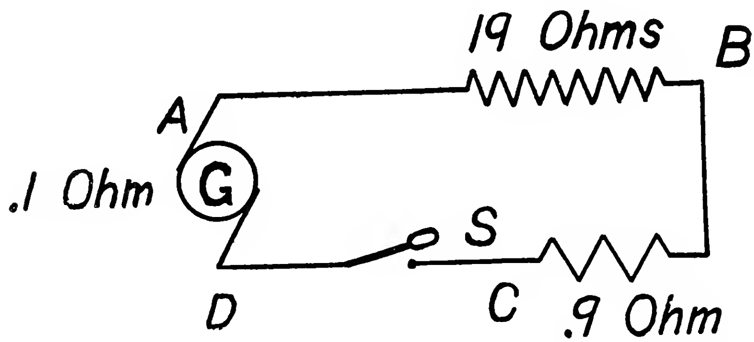

FIG. 2. Simple electric circuit.

ranges. From 0 to 15 ma. on one scale and 0 to 150 ma. on the other is the best for most work.

Do not try to draw 150 ma. when the meter is set for a maximum of 15 ma. If the pointer gets bent, due allowance must be made in reading.

Electric Circuit.—An electric circuit consists of some sort of a generator and a more or less complex conducting path between its terminals. Electricity *outside* a generator always passes from high to low voltage, and the current may properly be said to *lose voltage* en route from one generator terminal to the other.

Consider a very simple circuit, Fig. 2, consisting of a generator, *G;* generator resistance one-tenth ohm, two other

resistances as shown. The fundamental law of such a circuit is that if when the switch, S, is open we have, say 220 volts, then for any total resistance, R, we will have a current, on closing S, such that

Current x total resistance = 220, or in this case,
No. of amperes x $(.1 + .9 + 19) = 220$
Current, $I = \frac{220}{20} = 11$ amperes.

The voltage is used up as follows:

In the generator	11 x .1 =	1.1 volts
Between A and B	11 x 19 =	209.0
Between B and C	11 x .9 =	9.9
Total		220.0 volts

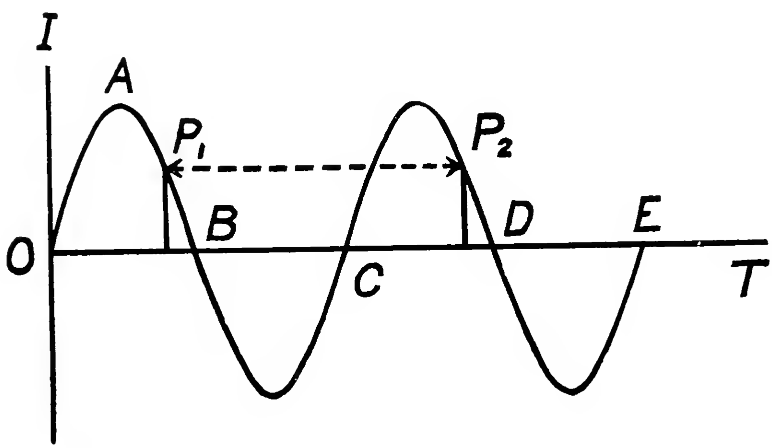

Fig. 3. Current-time curve of a simple a.c. circuit.

This relation is true for all circuits, viz., volts lost due to resistance of R ohms when a current of I amperes is flowing $= I\ R$.

Direct Current (d.c.).—When the electron-flow is in only one direction, the current is named direct. Dry cells, storage batteries, static machines, and d.-c. dynamos deliver

direct current. A current may be intermittent or pulsating, and still be called a direct current.

Alternating Current (a.c.).—When the electrons flow in one direction for a short time and then the flow decreases and a reverse flow occurs, we say the current is alternating. A.-c. dynamos are the only sources of true alternating current.

Such a current in its simplest form may be pictured by a suitable time-current diagram. In Fig. 3 time is shown as increasing from left to right.

$$\text{Let } OC = \frac{1}{60} \text{ second}$$

$$\text{Then } OC = BD = CE = P_1 P_2 = \frac{1}{60} \text{ second}$$

This current takes all its variable values once in 1/60 of a second, and repeats the operation 60 times in one second. It is designated as 60 cycle a. c. If drawn from a 220 volt service, its complete designation is 220 volt—60 cycle—alternating current of a certain number of amperes.

During the times *OB, CD, EF,* etc., current flows in the opposite sense to that during the times *BC, DE,* etc. Note that there are two *alternations* to each cycle, or 120 per second in this case.

X-Ray Current-Voltage Requirements.—At present x-ray tubes are used with currents varying approximately between 5 and 100 milliamperes, and at voltage running between 25 and 100 kv., i. e., 25,000 to 100,000 volts. This high voltage requirement cannot be met by simple d.-c. generators.

High Voltage.—The requisite voltage is secured by the use of:

1. The so-called static machine (direct but impractical).

2. The periodic *interruption* of a direct current through one coil, causing high voltage in a neighboring coil (induction coil).

3. Using a low voltage alternating current in one coil and getting a high voltage alternating in an adjacent coil (transformer).

The second device is still used to some extent, but has largely been displaced by the transformer in recent years.

The use of an induction coil or a transformer to increase voltage involves two distinct circuits, one connected through some control device to the supply line or generator, and known as the primary circuit; the other, insulated from the primary and connected to the tube terminals, known as the secondary circuit.

The primary always:

- Is of relatively low voltage.
- Is a moderately large wire.
- Carries a current of some *amperes*.
- Is reasonably safe to touch.
- Requires good metallic contacts at all connections.

The secondary always:

- Is high voltage.
- Is quite a small wire.
- Carries a current of some *milliamperes*.
- Is unpleasant and often dangerous to touch.
- Will pass current across loose connections or even through some insulating material.

The induction coil and a few transformers have both coils wound on hollow concentric cylinders, the primary within the secondary, and the space inside the primary coil is filled with thin iron sheets or wires. These are named open magnetic circuit devices.

Most transformers now in use have the iron in the form

of a closed rectangle, and the two coils wound so as to slip on the sides of this rectangle. These are known as *closed magnetic circuit* transformers.

The Gas Tube.—While a great variety of special forms of gas containing tubes have been introduced from time to time, the general form shown in Fig. 4 alone has survived for ordinary use.

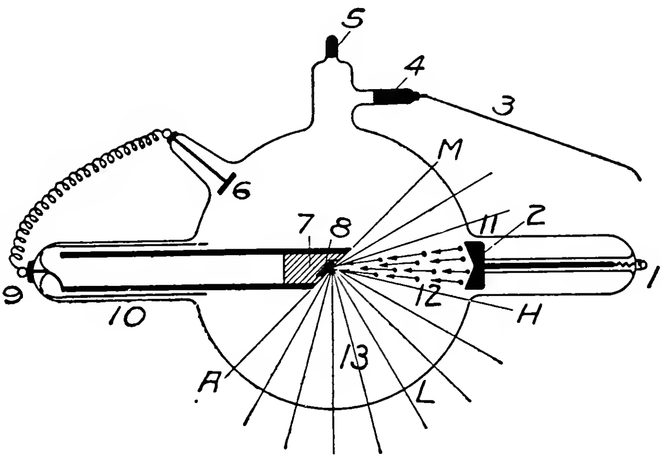

FIG. 4. Regular gas containing tube.

1. Negative or cathode terminal.
2. Cathode of aluminum.
3. Adjustable connections for softening.
4. Softening material.
5. Sealing off tip.
6. Auxiliary anode.
7. Copper block.
8. Tungsten button.
9. Positive or anode terminal.
10. Anode neck.
11. Cathode neck.
12. Cathode particles.
13. Path of x-rays.

A L M, Anterior hemisphere showing fluorescence.

The target material has a great influence on the behavior of the tube and the quality of the rays. The atomic weight must be high, as the fraction of cathode ray energy transformed into x-rays increases with increase of atomic weight. The melting point must be high or the metal will melt at the focus. It should conduct heat well, and must not vaporize readily below its melting point. The following table gives the approximate data relating to possible metals for this purpose. Taking platinum as a standard radiator:

Metal	At. Wt.	Amount of X-Radiation	Melting Pt.
Platinum	195.2	1.	1760. C.
Iridium	193.	.98	2300
Osmium	190.9	.97	2700
Tungsten	184.	.91	above 3000
Tantalum	181.	.90	2900

The essential features of *all* modern tungsten target gas containing tubes are shown in Fig. 4. Various minor modifications may be seen in tubes from different makers, but each part shown must be present in some form.

The cathodes may differ in shape, but only aluminum gives good results and long tube life. The mounting of cathode and target must be firm, and the position in the neck carefully chosen. The adjustable arm (3) is often absent, and a third wire is run to a variable spark gap connecting with the negative terminal of the machine. The auxiliary anode (6) has a great variety of forms; in many water-cooled tubes, and sometimes in others (6) and (10) are interchanged. Numerous special devices for conducting heat away from the target are in use and are

more or less effective. For treatment or for long fluoroscopic examination with this type of tube, water cooling is essential, and a good stream of air directed against the glass adjacent to the cathode is also of considerable assistance. A satisfactory tube must have a stable position of anode and cathode; all attempts to use an adjustable cathode have been unsatisfactory. The metal parts must be pre-heated and the tube itself heated during exhaustion. A well made and properly exhausted tube shows a good hemisphere on the anterior portion, and the remainder of the tube should show but little fluorescent light; a working tube should not be "flashy" or "cranky." When one attempts to operate a moderately hard tube at too low potential, this unstable state may result and either the voltage must be raised or the tube softened. The vacuum must be within fairly well-defined limits, averaging not far from .001 mm. pressure of mercury, and must be in some manner under control, if the life of the tube is of consequence.

The tendency of all gas containing tubes on low current is to "harden," i. e., to require more voltage for the same current, or, if the voltage is not changed, the current decreases. On operation above a certain power peculiar to each tube, the tube softens on account of heating; when this proceeds so far that the tube shows and maintains a purple glow marking out the cathode stream, it is useless until repumped.

Many devices have been used to soften tubes. The more common are the following:

1. A side tube containing mica, asbestos, etc., and through which a small discharge current may be sent, thereby liberating gas. (No. 4, Fig. 4.)

2. A special target is placed in a side tube to be bombarded by rays from a small auxiliary cathode.

3. A fine palladium tube projects through the walls of the tube; when this is heated by a small flame it allows hydrogen to pass into the bulb. This has been modified by Snook, where the tube is heated by a spark discharged from the operating transformer.

4. Heating the entire bulb. (Useless except in an emergency.)

5. A mercury-controlled porous valve allows air to pass slowly into the bulb when the inlet is not covered by the mercury (Heinz-Bauer).

2, 3, and 4 are rarely used in this country, although 3 (osmosis regulators) are sometimes seen outside the more useful Snook form.

The Coolidge Tube.—The great difficulty in the operation of the ordinary gas containing tube lies in the irregular supply of electrons and the impossibility of control of their development. When operated above very moderate power, the trend is always toward larger quantities of electrons and a consequent drop in penetration, unless the current is greatly increased, when a still greater supply is developed, so that there is no automatic self-protection of the tube.

Wehnelt found that a platinum ribbon coated with lime would allow of current transfer through a high vacuum at moderate voltages. Several attempts to use such a cathode for x-ray tubes were unsuccessful, and no modification of the standard tube appeared until it was found by Richardson and others that electrons were emitted by hot metals.

The simplest application of this principle to x-ray development has been worked out by Dr. W. D. Coolidge in the Research Laboratory of the General Electric Company at Schenectady. In this tube, the cathode is a spiral filament of tungsten wire, *A*, Fig. 5, heated to a high tem-

perature by a current from an *insulated* storage battery, or by a special transformer. The form of electrostatic field needed for focussing the electron stream is fixed by a small molybdenum cylinder, *B*, within which the cathode is placed. The target is usually a solid piece of wrought tungsten mounted on a molybdenum rod, around which collars are placed to distribute the heat conducted from the target.

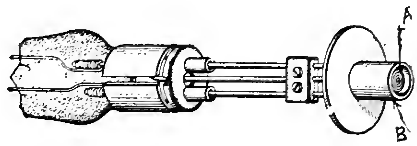

FIG. 5. Coolidge cathode construction.

Fig. 6 shows the Coolidge tube.

1. Cathode terminal.
2. Electron focusing cone.
3. Solid tungsten target.
4. Molybdenum supporting rod.
5. Anode terminal.

In order to operate properly, it was found that the highest possible vacuum must be attained. Not only was the greatest care required in pumping, but the metal

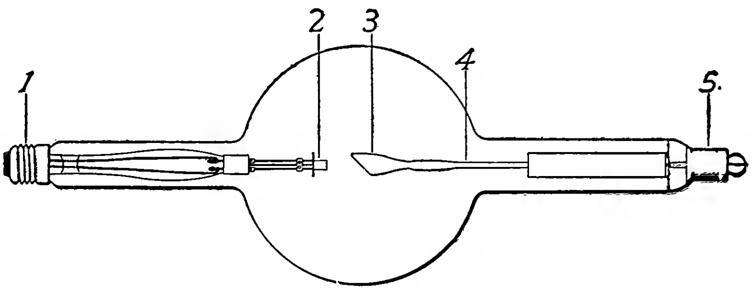

FIG. 6. Coolidge tube.

parts had to be freed from occluded gas by heating in a vacuum nearly to their melting point. In this tube there is no source of electrons except from the hot filament, and as this supply *depends only on the temperature of the filament*, the operator has perfect control of the number of available electrons by simply changing the auxiliary

current. A small transformer is now generally used to supply low voltage for the filament current. Connections are as shown in Fig. 7. The winding connected to the filament must be well insulated from case and primary winding.

The *current* through the tube cannot be increased after

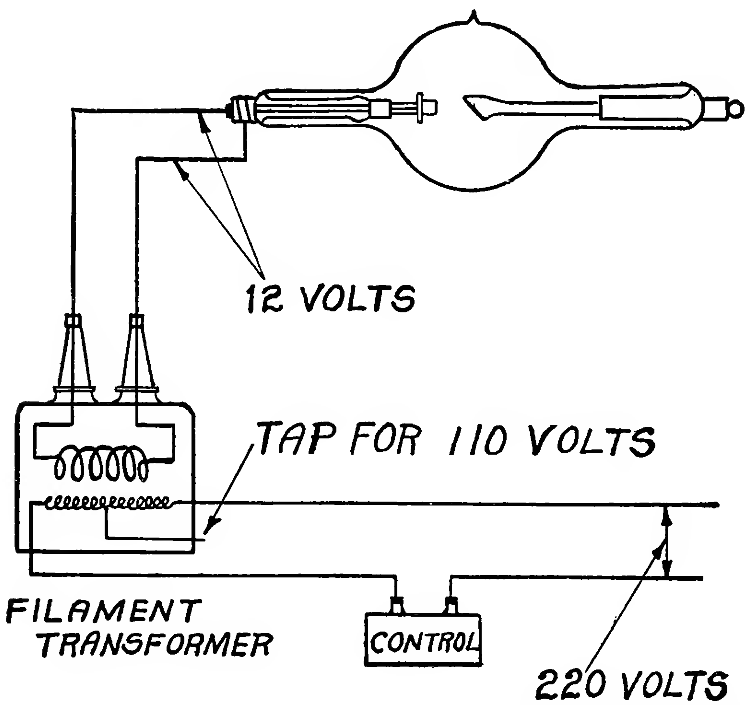

FIG. 7. Wiring diagram for step-down transformer to supply current for filament of Coolidge tube.

the supply of electrons is entirely utilized, no matter how much the *voltage* is raised. This maximum current for each particular filament temperature is named the *saturation* current, and until this is reached the voltage maintained between cathode and target may be too low for use. So long as the negative current reaching the tube does not exceed the number of electrons emitted per sec-

ond multiplied by the charge of each electron, there can be no charge piled up on the electrodes—i. e., no effective terminal voltage.

No Inverse.—A further valuable feature of the tube is its inability to transmit inverse *so long as the focal spot is not too hot.* On account of the increased strain on the glass, when inverse is present, it is well to include a valve tube when operating on a heavy coil.

Penetration Limits.—The highest operating voltage on the present tubes is about 100 kv., as measured on a special electrostatic voltmeter. This refers to "effective" voltage; the peak voltage is larger than this.

No doubt this can be increased by modification of the design, but insulation difficulties and danger of puncture will be increased as higher voltages are used. Such high penetrating rays as may now be reached are *not* useful in fluoroscopic work or in radiography, partly on account of the enormous amount of scattered radiation developed in the tissues of the body. Such scattered and corpuscular rays may, however, be useful in therapeutic work. Very soft rays may be produced in great abundance if the glass will allow them to pass out. Attempts to use too soft rays in radiographic work are always fraught with grave danger.

No Fluorescence in the Glass.—In marked contrast to the usual tube, there is no fluorescence of the glass walls except a slight illumination in the anode neck. Sometimes a minute chip in the glass or a slight evolution of tungsten vapor will give a momentary flash of green, but on further operation at moderate power this disappears. The bombardment of the walls of the tube by electrons reflected from the target or scattered from the gas atoms in the gas containing tube is the cause of the fluorescence and of a very considerable amount of soft radiation

originating in the glass. As there is in a gas tube as large a supply of positive ions as of negative, continual recombination results, and no negative layer can form on the glass walls to prevent bombardment by scattered and reflected electrons. In the Coolidge tube the absence of positive ions probably allows the accumulation of a negative charge on the glass, and as soon as established this layer repels electrons and the glass is no longer a target.

New Form of Coolidge Tube.—The ordinary form of Coolidge tube will operate satisfactorily without a rectifier *if the focal spot is at a temperature below that at which it gives off an appreciable number of electrons.* It follows that part of the problem of eliminating the rectifier is keeping the target cool. A new form of tube which will help greatly in this mode of operation has recently been developed by the General Electric Research Laboratory, Fig. 8. The target is a tungsten button set in a heavy copper backing which is continuous with a large copper rod extending out of the tube neck. To this are attached a series of discs acting as radiators. Operated within limits set by the manufacturers, this tube suppresses completely each alternate half wave and may be operated direct on a *suitable transformer.* At present these are designed for 10 ma. at a 5-inch gap for radiographic work, and for 5 ma. at the same gap for continuous duty in fluoroscopy. The wiring diagram then becomes very simple and easily understood.

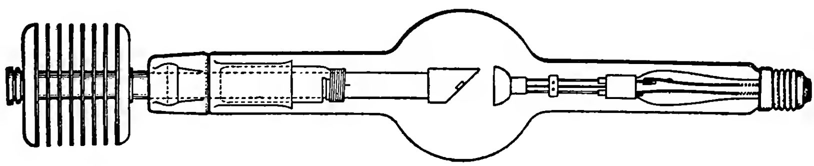

FIG. 8. Radiator type of Coolidge tube.

In Fig. 9 are shown a current-time curve and a voltage-time curve for the self-rectifying tube. In the latter *OA* is the working peak voltage which determines the tube radiation, and *BC* is the peak voltage of the suppressed wave which would give the spark gap reading.

A transformer should be used which will not vary its

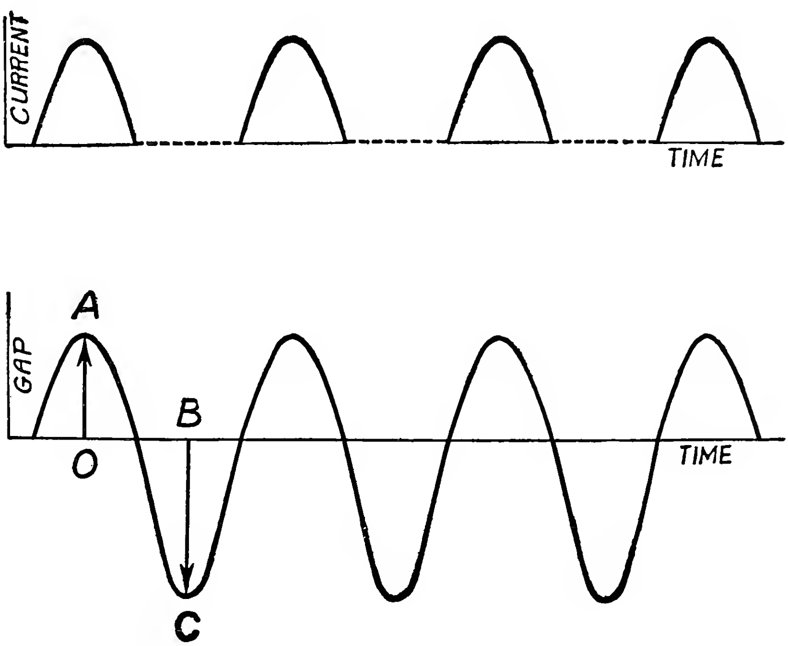

FIG. 9. Current and voltage curve for self-rectifying Coolidge tube. The voltage difference indicated by the excess of *BC* over *OA* will depend on design of transformer and control.

voltage too much from no current to that needed to operate it properly, since the voltage of the suppressed wave is quite decidedly higher than that of the one used, thereby causing spark-over and giving an incorrect idea of the actual working voltage.

The value of this arrangement for field work can hardly be overestimated, as there is no heavy and complicated rectifier. Operated from a small gas engine-driven gen-

erator, it is ideal for fluoroscopic work and satisfactory for emergency radiography. See U. S. Army Portable Unit, page 167.

Tube Focus.—The x-rays cannot be focussed by any known method, so that the terms focal point, etc., are misleading. *Electrons* can be directed by suitable cathode construction so that the greater portion strike a small area on the target. The diameter of this area is known as the "focus," and it is customary to speak of broad, medium, and fine foci. One can hardly state precise limits between these designations, but anything below 3 mm. would be extra fine focus; 3 to 4 mm. fine focus; 4 to 7 mm. medium focus; and over 7 mm. broad focus.

The size of focus is found by the use of a pin-hole camera, and should be given by the maker. Its size is important in two ways: First, in relation to the sharpness of image on plate or screen; second, as fixing the power that may be used without damage to the target. When an electron stream is maintained at high velocity against the target, there is a rapid rise in temperature which may result in vaporization or fusion of the metal. The rate of removal of heat by conduction is increased by broadening the focal spot, and the amount of metal suffering extreme rise in temperature is increased, so that for two reasons there is less danger of target damage.

The effect on sharpness of image is shown by using an exaggerated diagram as in Fig. 10. F_1 F_2 are the boundaries of the focal spot and 1-2 is the object. With the plate in plane *A*, had the only source been a point, F_1, a sharp shadow *PQ* would result; had F_2 been the only source, then *RS* would result. The only portion entirely shaded is *RQ*, and if the object is round, we have a central white spot with a variable shading out to a diameter *PS*. If the focal spot were very wide and the object very

small a plane *B* could be found beyond which there would be no white image.

The ring *PR* and *QS* is narrower the closer the object to the plate, the smaller the focal spot and the greater the target-plate distance. The apparent size of the shadow will vary somewhat with exposure, as regions partly shaded may be under-exposed when the exposure is brief and the true shadow may not appear at all.

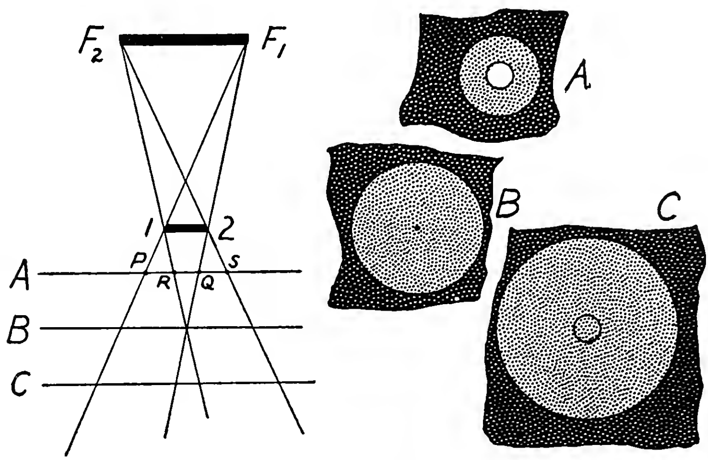

FIG. 10. Variation of size of shadows of small objects when a wide focus is used close to the plate.

Fine focus tubes are not needed in gastro-intestinal work, and should be used in other work with such care that the target does not become pitted.

Conditions for Operation.—Two things must be considered in the operation of x-ray tubes. The first is a proper supply of electrons as current carriers, the second a proper electric drive to force these electrons against the target. These two must be so related to each other that a proper voltage can be maintained when current is actually used.

No amount of milliamperage will serve to do radiographic or fluoroscopic work without a proper voltage consumption

at the tube. The potential difference or voltage drop across the tube is due to a piling up of positive charges and electrons at the target and cathode respectively and this must be done by the *generator.* When electrons move across from cathode to target they tend to relieve the congestion and, if the generator should fail to maintain the supply, the voltage and charge would disappear. The greater the number of electrons passing across in a given time, the more the terminal voltage will be reduced for a given ability of the generator to pump a new supply. The current is the charge of one electron multiplied by the number passing per second. Hence the greater the milliamperage, the greater the power demanded from the generator to maintain voltage and the more the drop in voltage from that shown on open circuit or on small current.

When the current increases, irrespective of the type of tube used or the design of the machine, the operating voltage will be reduced unless the rheostat or autotransformer control is moved to apply more power to the primary. *The spark gap on open circuit is no guide to the ability of the transformer or induction coil to keep up voltage when current is drawn.*

Inasmuch as reduced voltage very much more than offsets the effect of change of current in x-ray production as regards quantity, and likewise decreases the ability to pass through material, the proper maintenance of voltage is the most indispensable requisite in any x-ray installation. *By increasing exposure time nearly all work may be properly done at low current, but no increase of exposure time will compensate for too low voltage.*

The transformer must be designed for the voltage supply on which it is used, and it is very essential that the proper terminal voltage on the transformer primary should be maintained at all times and at all loads. After a machine

is once installed the operator has no control over these matters. The size of wire required to transmit current from the usual power transformer to the x-ray room will depend on the distance between the two transformers and on the voltage used. To transmit the same power at 110 volts as at 220 will require twice the current. Whenever a given current is passed over a resistance there is a voltage drop or loss. This loss is greater, the greater the current and the greater the resistance. When the line resistance and the current are known the voltage loss is found by taking their product. A loss of 2 or 3 per cent of the line voltage may be permissible. See line wiring, p. 70.

The operator must take care that the current through the tube does not drop the potential too much for the work required. For increased tube current the rheostat or autotransformer setting must be raised accordingly.

Gas Tube Characteristics.—The earlier type of tube depended for its supply of electrons on the breakdown of the atoms of its gaseous atmosphere, whereby the electrons and the positive remainder of the atom were separated and driven in opposite directions. This breakdown or ionization may be due to several causes:

1. The high electric stress between cathode and target.
2. The shooting of electrons through the atmosphere.
3. The passage of x-rays through the atmosphere.

The number of electrons set free will depend on the tube vacuum. If too few can be had, the tube is of too high vacuum and is called "hard." It backs up a very high spark gap, and may become "cranky." If too much gas is present the tube carries so much current that it is quite impossible to keep up voltage. The amount of free gas in the tube will increase as the parts of the tube rise in temperature, since gas tends to stick to a cold

surface. Therein often lies the explanation of failure in radiography on prolonged exposure.

The rate of softening of a gas tube operated at a given initial current and voltage varies with its original exhaustion and its use afterward. On low power with small current and high voltage there is a marked tendency to *reduce* the amount of free gas and thus raise the vacuum. When this tendency is just balanced by the evolution or release of gas by heat the tube runs at a nearly uniform current and voltage. On slightly higher power it will soften and the rate of softening will generally be greater with a new tube than in case of a well-seasoned one.

Danger in Testing.—It is unwise to test a gas tube at the power used in gastro-intestinal or other heavy work, as it is likely to over-soften before a milliammeter can be read or spark gap really ascertained. The usual recourse is to note current and gap at low power, and assume that when this is properly adjusted on, say, button *X*, it will give a proper result on a higher button *Y*. Careful study of these tubes shows that this is only approximately the case, for not only will tubes vary one from another, but the same tube will behave differently on different days. No better method has been suggested, however, so the operator should endeavor to season a tube, if possible, before attempting fast work.

Coolidge Tube Characteristics.—The electron supply in the Coolidge type of hot cathode tube is due entirely to the hot tungsten filament, as all the gas it is possible to remove has been taken out in pumping. The current carried by the tube is limited by the rate of electron supply and is thus determined solely by the filament current. This maximum *tube* current at a given *filament* current is only attained at a sufficiently high voltage and this voltage *increases* as the filament temperature is raised. When all

the electrons are being driven across as fast as they are produced, the corresponding current is named the *saturation* current. After such a current is reached the voltage may be greatly increased without a rise in tube current. Fig. 11 shows this characteristic of the tube, quite different from the gas-containing tube where higher applied voltage

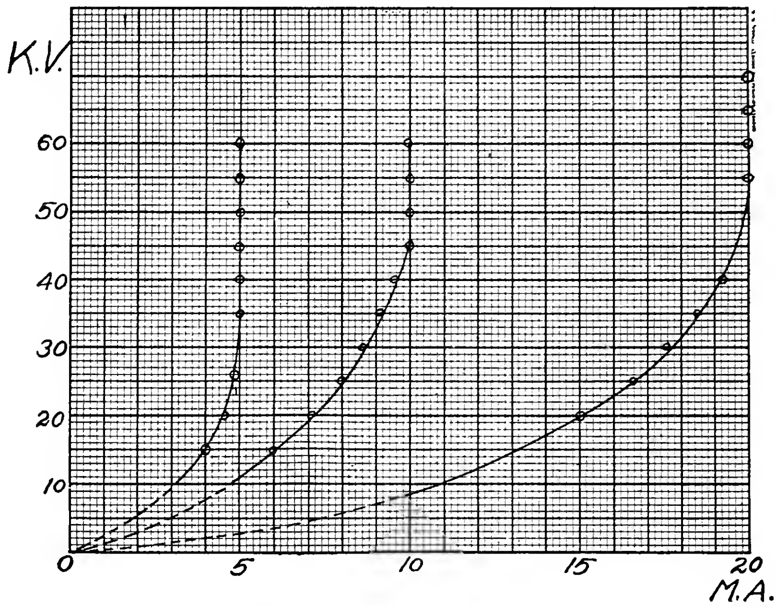

FIG. 11. Current-voltage lines of Coolidge tube for fixed filament temperatures. Vertical portions are above "saturation" points.

brings increased current. On account of the *great* increase of tube current resulting from a *slight* rise in filament current the writer has found it impractical to depend on the filament ammeter as a guide to tube current, especially when using rheostat control. In fact better work is done where no dependence is put on anything except spark gap and *tube* current.

Outflow of Radiation.—As radiation proceeds from the origin on the target it spreads out and flows through the

surfaces of larger and larger spheres. The amount received in a given time by any *fixed* area then decreases as the distance of the receiving surface is greater. This decrease always follows the *inverse square* law. Thus if 100 arbitrary units reach a given area at 10 inches from the target, the *same area* 20 inches from the target will only get ¼ as much in the same time, i. e., 25 units. At 30 inches the *same area* receives but 1/9 as much or 11 1/9 units. Or to get the *same* radiation to this area at the increased distances the time must increase as the *square* of the *distance,* i. e., if at 15 inches 2 seconds are required, at 20 inches $2 \times \left(\frac{20}{15}\right)^2 = 2 \times \frac{16}{9}$, at 25 inches $2 \times \frac{25}{9}$, at 30 inches $2 \times \left(\frac{30}{15}\right)^2 = 2 \times 4 = 8$ seconds, etc.

Amount of Radiation.—The measurement of x-ray radiation has proved a rather difficult matter and need not be fully discussed here. For our purpose the photographic measure is sufficiently accurate and determines the usefulness of the rays in practice. Whatever the conditions of operation, we might take a time of exposure so as to get the same blackening on two spots on a photographic plate, and then say that the two *had the same exposure,* when exposure does not mean time of tube action alone.

Such a method measures only the effect of rays used in changing the emulsion, *not* the total beam, the greater portion of which passes through the film.

Quality.—Fully as important as the amount of radiation is the quality or distribution of radiation among various wave lengths. Quality determines the ability of the rays to pass through flesh and bone, and was roughly gauged by the use of penetrometers. It depends on the voltage used to drive the current across the space between cathode

and anode, and is best expressed in terms of voltage or gap.

Dependence of Quantity on Electrical Conditions.—It is very important to realize that the amount of radiation as measured by the photographic effect is simply related to the electrical conditions under which a tube is operated.

If we let I = Current in milliamperes
V = Effective voltage in kv.

Then radiation leaves the target at a rate depending on the product of current and the *square* of the voltage. The amount reaching a given area placed at right angles to the flow and at a distance d from the target and in a time t is measured by $\frac{I\,V^2\,t}{d^2}$

Thus if $I_1, = 40$ ma., $V_1 = 30$ kv., $d = 20$ inches, $t =$ 1 second, in one case, and

$I_2 = 10$ ma., $V_2 = 60$ kv., $d = 20$ inches, $t = 1$ second in another, then Q_1 = 40x30x30x 1/400 = 90 arbitrary units where Q_1 = amount of radiation in the first case and Q_2 = 10x60x60x1/400 = 90 units in the second case. That is, 40 ma. at 30 kv. and 10 ma. at 60 kv. will produce the same quantity of x-rays as measured by photographic effect.

However, the radiation produced at 60 kv. is better able to penetrate any piece of matter, and a higher percentage passes through, so that a plate exposed partly to one and partly to the other through a block of material will show much more darkening for the second case, even though the quantities of radiation generated at the tube are equal. It would darken the plate equally if no body were interposed.

No matter what amount of current is passed through a tube it is useless for radiographic or fluoroscopic work, unless a voltage able to break down from 2 to 6 inches

of air between blunt points is used. For thick parts the higher voltage (gap) must be used.

The relation of sparking distance (between blunt points) to kilovolts is shown in Fig. 12. The kilovoltage is approximately ten times the gap in inches plus ten.

Penetration.—The most characteristic feature of x-rays

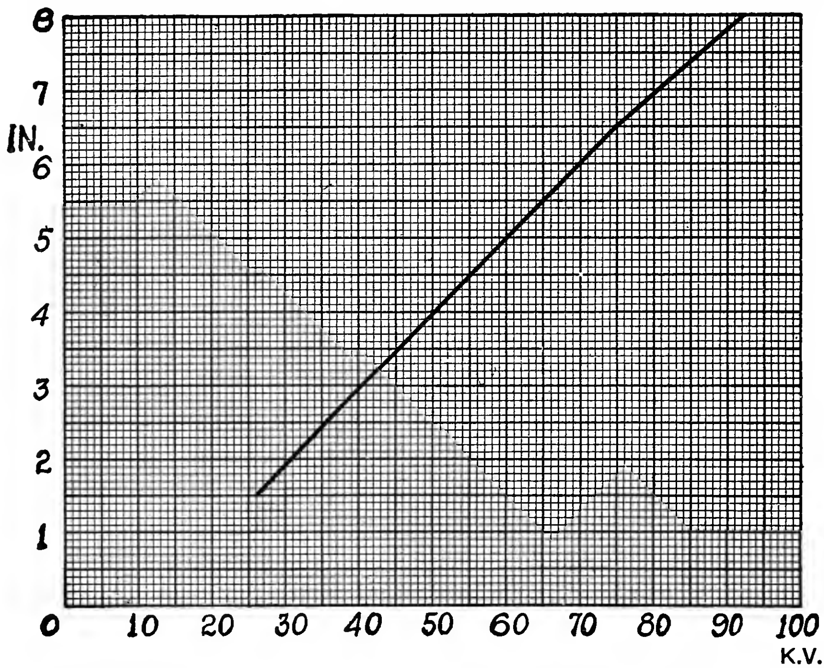

FIG. 12. Approximate relation between effective kilovolts and spark gap for moderately blunt points.

is their ability to pass through material quite opaque to other types of radiation. In all cases there is some absorption, but the rate of absorption or the amount left after passing through any layer of material varies according to the composition of the x-ray beam. The most penetrating rays are produced only at higher voltages. This penetration could be accurately defined in the case of a beam of one wave length, but it is quite difficult in the case of an actual complex beam.

It is essential for the operator to realize that increasing the tube voltage will (a) add shorter and more penetrating rays; (b) increase the quantity of the less penetrating which were produced at the lower voltage.

X-Ray Transformer.—There is no practical means of directly generating an electric current at the voltage needed in the production of useful x-rays, hence it is necessary to use a transformer, stepping up low voltage current to the high voltage required. The transformer consists of two coils of wire around a common iron core. For complete insulation of the coils from each other the system is immersed in oil or in wax. If in the latter, it is shipped complete; when oil insulated, the oil is usually shipped separately. In this case, it should be siphoned into the transformer; the inlet side should be raised an inch or so to get complete expulsion of the air. It is well to operate at a low power, allowing sparks to pass across an inch gap for some time to dislodge small air bubbles before putting it into service.

Use no oil not furnished for the purpose by a reliable manufacturer; *the oil must contain no moisture.*

Examine the oil level every two months to be sure it fills the tank. An exposed coil is sure to break down by puncture of the insulation. The top of the case should be kept free from oil and dirt. For protection against surges or sudden high tension pulses which are likely to damage the transformer, a resistance should be placed in shunt with the low tension terminals. If this is not provided by the maker, ordinary lamps may be used. Fig. 13.

The middle of the secondary is usually connected to the case (grounded); this insures a distribution of potential equally above and below the "earth" potential. Thus, if the terminal voltage is 40,000 volts, then the tendency to

pass a spark to any grounded conductor is 20,000 volts. This arrangement avoids in some measure the tendency to discharge to patient, stand, and tube that would result if the full terminal voltage were effective to earth.

Care must be taken to keep all contacts on the low voltage side tight. See that low tension wires are kept as far away from the high tension terminals as possible. If trouble actually occurs, due to short circuit or break inside

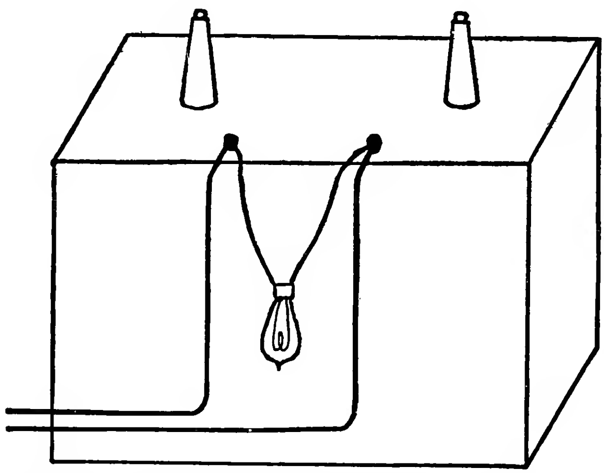

FIG. 13. Protection from surge by use of a lamp.

the transformer, there is no use in trying to repair it, as a rule, unless the trouble is close to the terminals. If there is trouble arising from sparking across between the high tension terminals of the transformer, attaching small spheres will relieve the tension and usually cure the trouble, or insulating barrier plates may be used.

Control of the Transformer.—Corresponding to each of the various high tension voltages maintained at the tube terminals, there must be applied a definite voltage across the primary of the transformer. The transformer changes voltage approximately in the ratio of number of turns in the primary to number of turns in the secondary, and

changes current in the inverse ratio. Thus a particular x-ray transformer might be wound with 500 turns in the secondary for each turn of primary, and it would be said to have a step-up ratio of 500. The secondary voltage would be 500 times the voltage in the primary and the secondary current 1/500 of that in the primary.

A table of the voltages that must be supplied and maintained at the primary terminals to give various high tension voltages can easily be made in this case.

Primary Applied Voltage	Resultant H. T. Voltage	Spark Gap (approximate)
80 v.	40 kv.	3 in.
90	45	3½
100	50	4
110	55	4½
120	60	5
130	65	5½
140	70	6
150	75	6½
160	80	7
220	110	10

Such primary voltages can be secured from a line supply of 220 volts (a) by the use of a rheostat, (b) by the use of an autotransformer.

Rheostat.—The rheostat is an adjustable resistance used to consume a part of the line voltage and leave the proper voltage to be applied at the transformer. Suppose, for instance, it is desired to have 40 ma., at a 5-inch gap delivered to the tube. The *primary* must be supplied with 120 volts and a current of 40 ma. x 500 = 20 amperes. In this case the rheostat must consume 100 volts from the 220 volt line with a 20 ampere current, Fig. 14. By

Ohms law ($V = IR$) the voltage consumed in the flow of current through a resistance is equal to the product of the current in amperes and the resistance in ohms. Therefore, $100\ v = 20 \times R$ from which $R = 5$ ohms, hence we would need 5 ohms of the rheostat to get the setting desired.

The rheostat consists of coils of resistance wire connected end to end, one end of the series being permanently connected to one wire of the power line. Re-

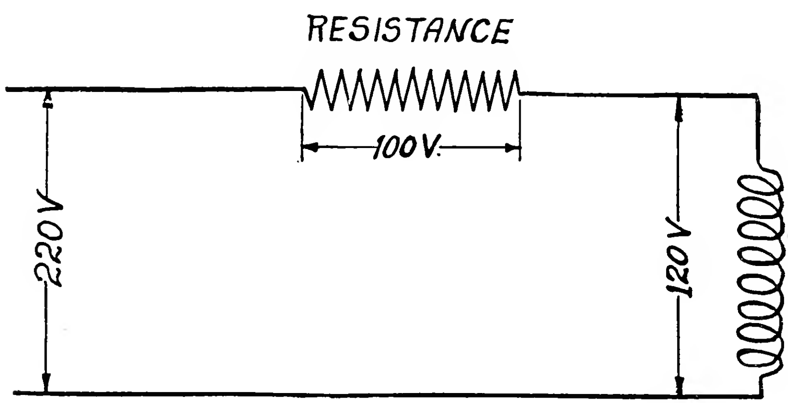

FIG. 14. Diagram showing consumption of voltage by primary of x-ray transformer and series resistance for a particular case.

sistance wire is made of some special material of considerably higher resistance for the same diameter and length than copper. An adjustable contact is used to join one transformer terminal to any desired point of the rheostat so as to include the required amount of resistance in the circuit. Fig. 15 shows the essential parts of a rheostat.

The usual numbering makes the power increase as the control lever is moved over to higher numbers. A good rheostat should be of substantial construction, well ventilated, and of such current capacity as not to get overheated under any operating conditions. It should be so

graded as to give 30 to 70 ma. on a 4-inch to 7-inch gap for radiographic work and from 3 to 5 ma. on a 9 or 10-inch gap for treatment.

The use of a rheostat to control tube voltage has the disadvantage that slight variations in tube current result in serious changes in voltage. To see how different tube currents cause such enormously different voltages on the same control setting, let us first construct a table to give the primary currents corresponding to different tube currents. Each primary current is 500 times the corresponding secondary.

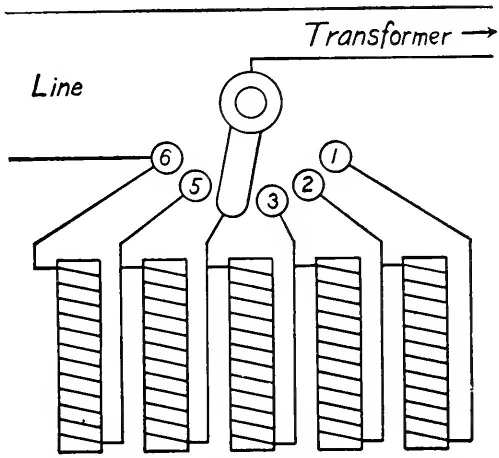

FIG. 15. Rheostat construction and connections.

Secondary Current	Primary Current
0 ma.	0 amps.
10	5
20	10
40	20
60	30
80	40
100	50

Assuming the setting of 5 ohms resistance, let us see how the voltage applied at the transformer varies under different loads. The voltage consumed in the rheostat is $V = I R$, where I is primary current and R is constant at 5 ohms.

Secondary Current	Primary Current	Voltage Consumed in Rheostat	Voltage left over to apply at primary	Resulting secondary voltage
0 ma.	0 amp.	0 v.	220 v.	110 kv.
10	5	25	195	97
20	10	50	170	85
40	20	100	120	60
60	30	150	70	35
80	40	200	20	10
100	50	250	—	—

These figures are represented graphically in Fig. 16. This results in the theoretical chart line corresponding to operation on the particular rheostat control button selected. For simplicity, no account has been taken in these figures of line wire resistance, resistance in the windings of the transformer, "magnetic leakage," and other factors which enter to a greater or less degree.

The voltage "regulation" under various loads of a rheostat controlled transformer is poor. On any one control setting the voltage will fall off very rapidly with an increase in current, and rise rapidly with a decrease. In Fig. 16 at 60 kv. and 40 ma. an increase of 8 ma., due to softening of a gas tube during exposure or to fluctuation in the filament temperature of a Coolidge tube, will lower the voltage 10 kv., or about an inch of spark gap. The loss in voltage and penetration will have considerably more influence on a plate than the increase in current. Also, if there were a break in the Coolidge filament line, or polarity were wrong, so that no current flowed in the secondary circuit the primary voltage would rise to that of the line with considerable likelihood of sparking to the patient or causing damage to apparatus.

Auto Transformer.—To secure better voltage main-

tenance under varying loads an autotransformer is often used. It consists of a continuous coil of wire wound around an iron core with taps taken out to control buttons at proper intervals, as shown in Fig. 17. If alternating cur-

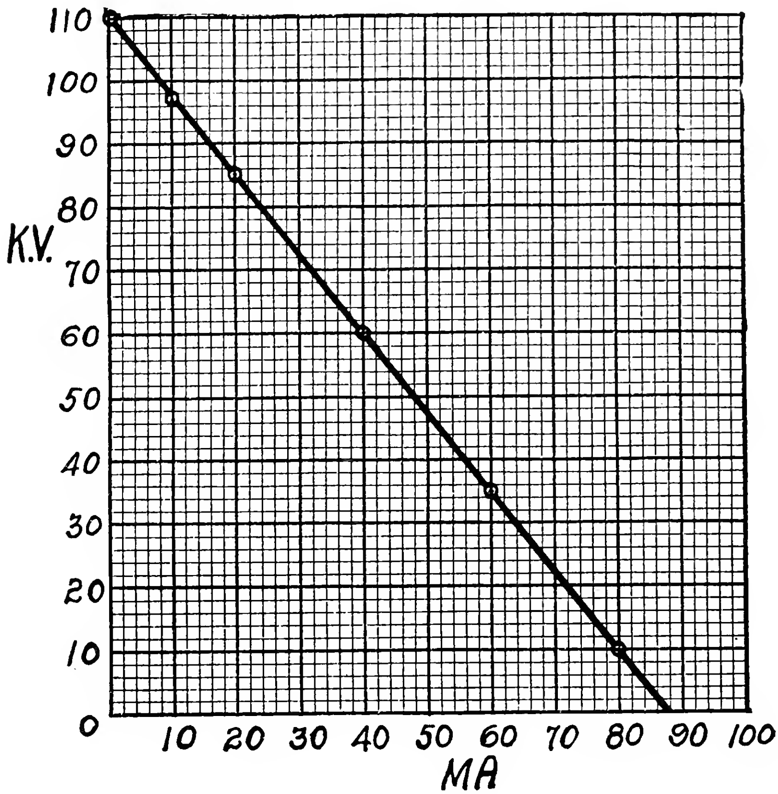

Fig. 16. Theoretical chart line plotted from data given in table on page 52. This line shows, for the particular machine and setting, the voltage at which various currents will be delivered.

rent be applied to the complete winding of such a coil there will be a voltage induced in any part of the winding, bearing the same relation to the applied voltage that the number of turns of this part of the winding bears to the number of turns in the whole coil. It is essentially the same as any other transformer, except that primary and secondary

are part of the same continuous wire rather than separate windings, and its action depends on self-induction in a single coil rather than on mutual induction between two coils. The ratio between the number of turns in the primary and secondary circuits is changed by setting the control lever

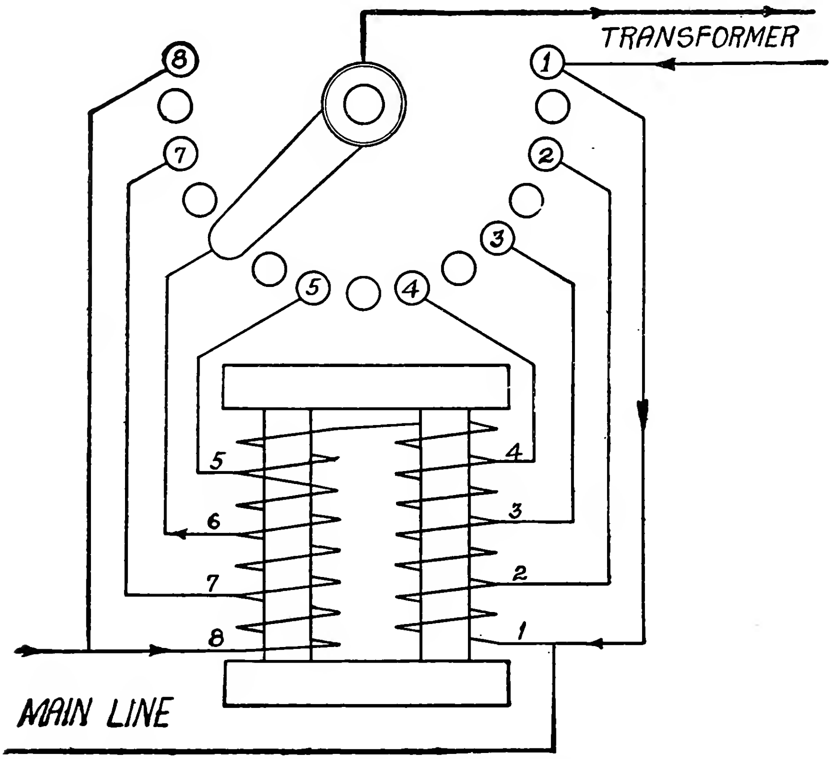

FIG. 17. Wiring diagram of autotransformer. Notice dead buttons between the active ones which are numbered.

on the various buttons. The autotransformer is used as a control device to reduce the line voltage to that which is applied to the x-ray transformer primary, hence it is a step-down transformer and has fewer turns in the secondary circuit than in the primary. As the control handle is moved to higher readings, more turns are cut into the secondary circuit and higher voltage is applied to the

primary of the x-ray transformer. Blank or "dead" buttons are placed between adjacent live buttons, which differ from each other by a few volts, to prevent a short circuit of this low voltage by the control lever being in contact with two live buttons at one time.

The autotransformer is more suitable than a variable ratio step-down transformer, which might be used, since it saves wire and iron, being much smaller for equivalent capacity, and therefore cheaper to build. The autotransformer principle cannot be applied to x-ray and filament transformers because their ratio is too large and the primary and secondary must be insulated from each other.

The autotransformer, like an ordinary transformer, is very efficient and does not change electric energy into heat like the rheostat. The windings are of large copper wire, with low ohmic resistance. When increased current is demanded from an autotransformer, it simply draws more current from the supply line and delivers the current demanded with very little drop in voltage.

When increased current is demanded in the tube, it will be supplied by an autotransformer with far less voltage drop than is the case with the rheostat. Fig. 18 shows the behavior of the two devices on a particular machine. Starting at 10 ma. and 60 kv., and raising the tube current on a fixed rheostat setting, gives the series of currents and voltages shown by the line *AC;* while on a fixed autotransformer setting we have the line *AB*. Since the quantity of radiation (measured photographically) increases as the current and the square of the voltage, we may compute the *relative* amount of radiation regardless of penetration. Curve *DE* shows the rheostat delivery down as low as useful rays are produced; *DF* shows the delivery on the autotransformer up to 60 ma.

This form of control is of special value when the fila-

ment current of a Coolidge tube is not entirely steady. Thus, if the tube current in the case cited changed from 10 to 15 ma., with a rheostat control, the radiation would be reduced in quantity from 32 to 25 arbitrary units and also would be much less penetrating; while with the autotransformer the same change would result in an *increase*

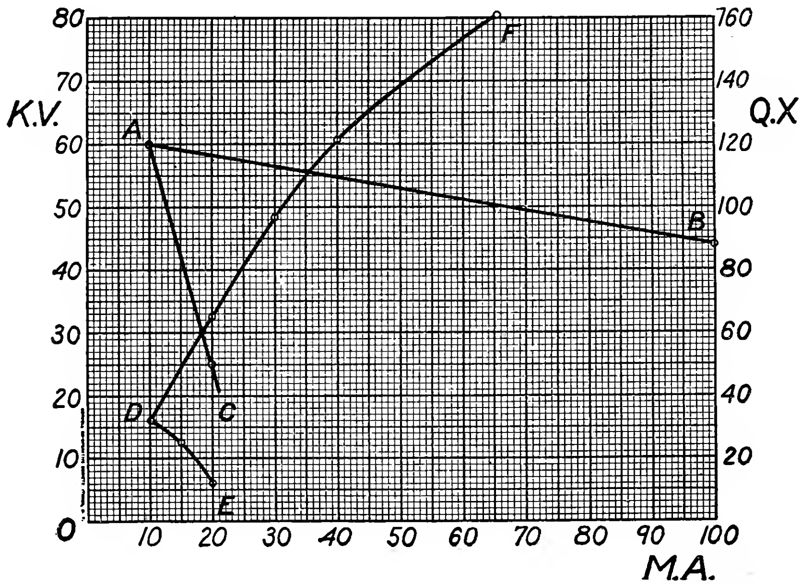

FIG. 18. Relation of x-ray production on two types of control. On rheostat control we have *AC* as the voltage-current line. Voltage ordinates at the left. *DE*, corresponding x-radiation quantity, ordinates at the right. *AB*, autotransformer chart line. *DF*, corresponding quantity line. Quantity in arbitrary units.

in quantity from 32 to 50 units very slightly less penetrating than at 10 ma.

"Inductance" Taps.—Instead of controlling completely by variation in the applied voltage, in some instances the winding ratio of the x-ray transformer is variable by a dial switch which cuts in more or less turns of the transformer primary. The lowest ratio of step-up corresponds to the complete primary and, since the secondary winding

is fixed, to cut out turns of the primary will increase the step-up ratio and give higher secondary voltage. As usually applied, the machine has essentially a rheostat control, with rheostat rather than autotransformer characteristics, and usually more taps are made in the winding than serve a useful purpose.

The same principle is conveniently applied in transformers built to operate on either 220 or 110 volt mains, half as many primary turns being used for 110 volts as for 220. The bedside unit uses this principle for 110 volt a.c. and the lower voltage a.c. obtained from the rotary converter. In some instances the primary is wound in two sections which are connected in series for 220 volts and in parallel for 110 volts, in the latter case giving carrying capacity for the heavy primary currents as well as the higher step-up ratio.

Transformer Chart.—A proper procedure in handling machine and tube is indispensable. Such a method should be adopted as will

1. Save time and tubes.
2. Render reproduction of results possible.
3. Apply to all machines.
4. Require a minimum amount of instrument reading when operating.
5. Indicate the working range of the machine.

The working spark gap, with moderate sized blunt points for a gap, varies from about 3 inches to 6 inches, and currents vary from 5 to 100 milliamperes in fluoroscopic and radiographic work. Any possible combinations on the machine, giving settings outside these limits, are practically useless.

On any transformer outfit find first a 5 ma. 6-inch gap setting, then a 40 or 50 ma. 6-inch gap or an 80 ma. 4-inch gap setting. Study no settings outside these limits. In

Fig. 19 take rheostat setting G as an example. *Read the current through the tube when a 6-inch gap just fails to break* (25 ma.). Record your setting and the current. Leaving the x-ray transformer *control unchanged* find the tube current at which a 5-inch gap just fails to break. Do the same for a 4- and for a 3-inch gap. When these readings are plotted to scale, as in Fig. 19, they should

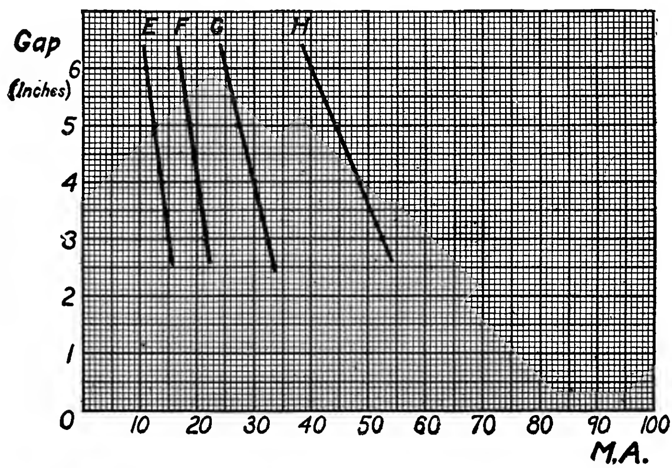

FIG. 19. Partial "chart" of a particular machine with rheostat control. Note that gap change, as tube current increases, is very rapid. On G, for example, we have a 6-inch gap at 25 ma. and only a 5-inch gap at 27.5 ma. or a change of an inch for each 2½ ma. Compare with Fig. 20.

fall nearly on a straight line. If they do not do so, repeat the observations.

So long as the power supply is kept at the voltage prevailing when this chart was determined the coördinates of a line give all the currents and voltages at any time available on the indicated rheostat setting. H gives the currents at which gaps between 6 and 3 inches are broken on button H. Fig. 20 shows five such lines for a particular machine on autotransformer control.

How to Use the Chart.—Using chart, Fig. 19, one needs

for a particular case 20 ma. at a 4-inch gap. The vertical line through 20 cuts the line marked *F* at the 4-inch gap. Hence we must use button *F*. Have spark gap open to seven or eight inches as a safety valve and forget it entirely. Move rheostat lever to *F*, look at your milliammeter, use one hand on transformer primary switch and the other on the Coolidge control. Close transformer switch and bring filament control to a setting, giving 20 milliam-

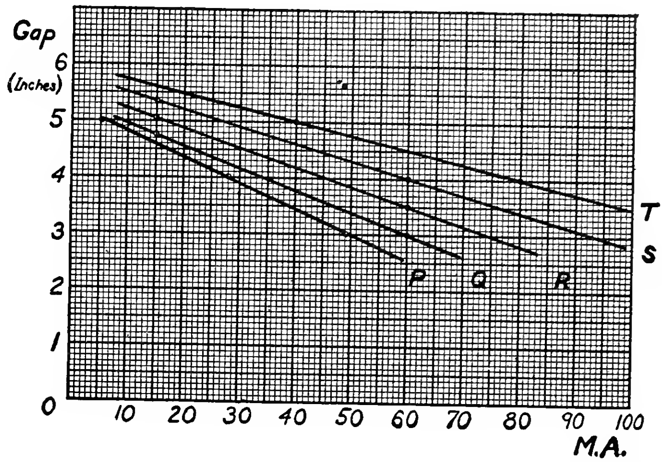

FIG. 20. Partial "chart" of the same transformer using autotransformer control. Note that line marked *P* shows all *useful* currents that can be had on this setting: changing from 5 ma. to 50 ma. lowers gap from 5 to 3 inches.

peres tube current; there is no need of testing the spark gap.

Do not try to read the milliammeter on the throw. Learn to start and set your machine within 10 seconds. On 20 ma. desired, a current of 19 or 21 ma. is close enough for this work.

Using chart, Fig. 20, for 45 ma. at a 4-inch gap, go at once to *R* and proceed as before. A little time spent in making this chart and in using it will reduce time lost and failures. Note that the faster the spark gap falls with

increase of tube current the more accurately must the filament current be adjusted and maintained.

Synchronous Motors.—A synchronous motor is one that makes either the same number of revolutions per minute as the generator feeding it or a fixed fraction thereof. Thus, if fed by a 60 cycle alternating current, there are 7200 alternations per minute. One alternation is produced whenever a conductor passes one pole piece of the generator. Thus, a 60 cycle current from an eight-pole machine requires 900 r.p.m (revolutions per minute), since 7200 = 8 x 900. For a four-pole machine we must have 1800 r.p.m., etc. A four-pole motor must then make 1800 r.p.m. for synchronism if on such a circuit, and it must not make 1801 or 1799. Since the rectifier for a 60 cycle current must make a quarter-turn each 1/120 of a second, the motor must turn at 1800 r.p.m. It must be observed that such a motor is designed for a given frequency and cannot be expected to work on one greatly different from that intended.

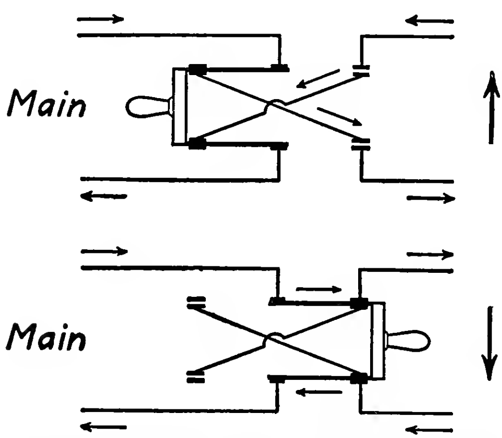

Fig. 21. Wiring of "polarity" switch.

Starting.—Many motors require connection to a special starting device in order to bring them up nearly to the required speed before making the running connection. Do not delay too long, and do not throw over the switch too quickly. A little practice will enable you to tell by the sound of the machine when the speed is about right.

Polarity Indicator.—Some machines have a field wind-

ing which ensures the same terminal polarity each time the machine is started. In most machines there is as much chance of a given terminal starting + as —. Polarity indicators are often used to show which way the rectifier comes into step. Either a primary reversing switch, Fig. 21, is used or the motor switch is opened for an instant and again closed, thus allowing the motor to drop back with

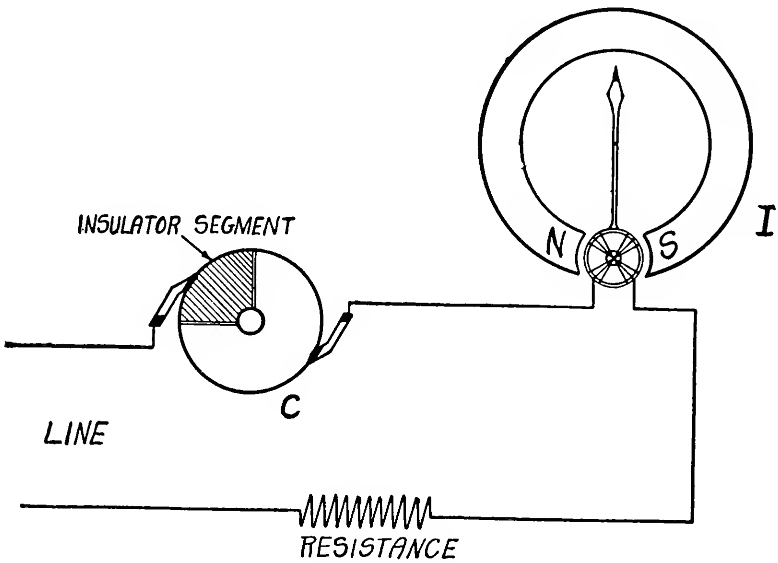

FIG. 22. Principle of polarity indicator. Note resistance in series.

the chance of changing polarity of the high tension lines. These indicators are devices to indicate direction of current flow, used in connection with a small low-tension rectifier driven by the motor. In Fig. 22 a source of alternating current is obtained from the primary lines; *C* is the low tension rectifier, or commutator, fastened on the same shaft as the high tension rectifier, and *I* is the indicator.

The direction of the rectified current through the indicator circuit will be one way or the other, depending on how the two rectifiers happen to come into step. The indi-

cator itself consists of a movable coil with pointer attached, working against a hair-spring in a permanent magnetic field, and it is very similar in construction to a direct current voltmeter or ammeter. If the rectified current flows one way through the coil, the needle will be deflected to on side; if the current flows in the reverse direction, the needle will swing to the opposite side.

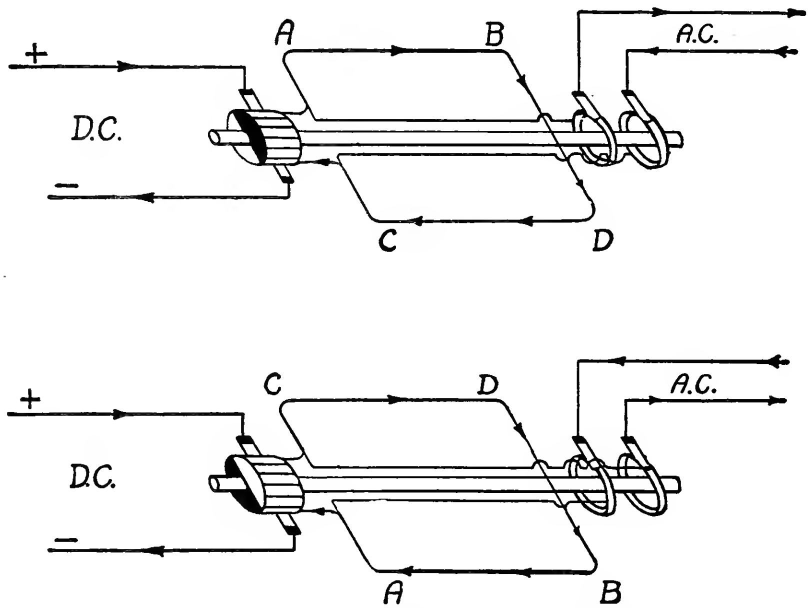

FIG. 23. Principle of rotary converter showing two positions of active coil 180° apart, armature current being always alternating.

The indicator is usually of low resistance with an auxiliary resistance unit included in the circuit to prevent burnout of the indicator coil. Never connect the indicator without this resistance in circuit, and in testing to find the proper connections always use a lamp in series with the indicator to prevent burnout, if connection is accidentally made to too high voltage.

Rotary Converter.—If the line supply is direct current it must be changed into alternating by means of a rotary

converter, since the x-ray transformer will operate only when its primary is supplied with alternating current. The operation of the converter is based on the fact that the current flowing through the armature of a direct-current motor is alternating. To simplify explanation, consider the case of a machine having two field poles and a single armature coil. At the left, Fig. 23, are the brushes to which the direct current line is connected, and at the right those from which the alternating current is drawn. The flow of current through the armature coil in the direction of the

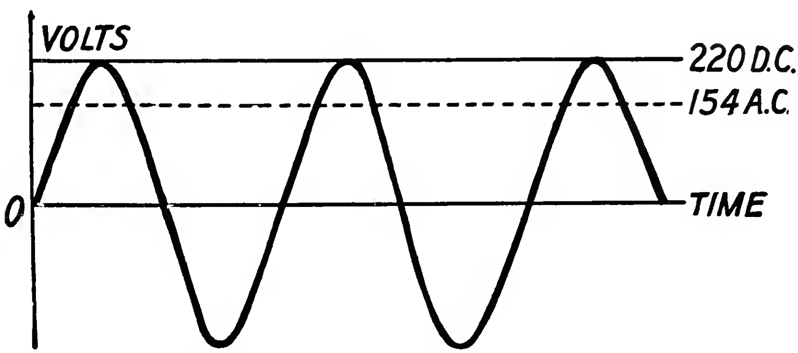

FIG. 24. Relation between d.c. voltage supplied and a.c. voltage delivered.

pointers causes rotation of the coil as indicated, owing to the reaction with the magnetic field between the stationary pole pieces. When the coil has rotated just beyond the vertical plane the connection of the rotating commutator segments with the d.-c. feed brushes is reversed, the current through the armature coil is reversed, and rotation is thereby made to continue. Each half revolution of the armature causes a reversal of current through the armature winding and a change in polarity of the two segments. If, now, these segments are continuously connected to the same collector brushes by means of slip rings, the current drawn from these brushes will be alternating current.

The direct-current voltage supplied to the rotary converter corresponds to the peak voltage of the alternating current wave, and the effective voltage of the alternating current is only about 70 per cent of this, Fig. 24. Thus a converter operating on 220 volts d.c. will deliver only 154 volts a.c. and if 220 volts a.c. are required, it is necessary to step up by means of a special transformer or autotransformer. Under heavy load the voltage will fall considerably below the 70 per cent, and serious difficulties will arise from trying to use a rotary converter too small for the demands placed upon it.

In direct-current x-ray machines the rotary converter drives the rectifying device. In this case, the machine always starts up with the same high tension polarity, and a polarity indicator or polarity switch is unnecessary. If polarity is wrong permanently, interchange the primary lead wires at the transformer or reverse the tube in the stand.

In using a rotary converter, one should remember that all the power used passes into the rotary through the d.-c. brushes, and all used by the x-ray transformer passes out from the slip rings. In the a.-c. machine the transformer power does not pass through the motor, so that greater care of brushes, etc., is needed in the d.-c. machine.

A considerable proportion of failures of rotaries is due to the breakdown of insulation at the connection of the armature wires to the slip rings. "The Care of Motors" on page 84 applies also to rotary converters. Protection should be made against high tension surges by connecting an incandescent lamp across the a.-c. end, as is done to protect a transformer, Fig. 13.

Rectifier.—Two forms of rotating circuit changers are in common use, the cross-arm type and disc type. Both are run by a synchronous motor, and they must be correctly

placed relative to the motor armature if efficient delivery is to be secured. Fig 25 shows the current path for the four-arm type, Fig. 26 for the two-arm, and Fig. 27 for the disc type.

In Fig. 25 when the right hand terminal of the transformer is –, the flow of negative charge or of electrons is from *A*-*B*-tube-*C*-*D*. If the spindle turns 90° while the polarity of the transformer is reversed, electrons flow from

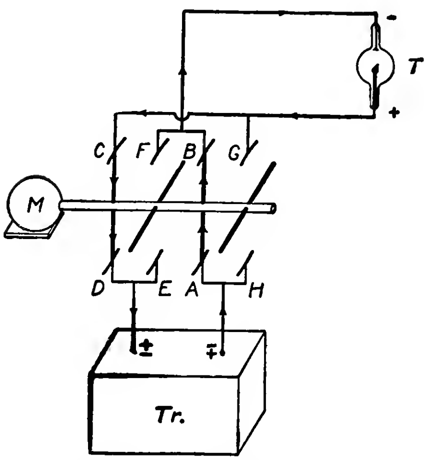

FIG. 25. Secondary circuit of Snook machine. Cross-bar type rectifier—four arms.

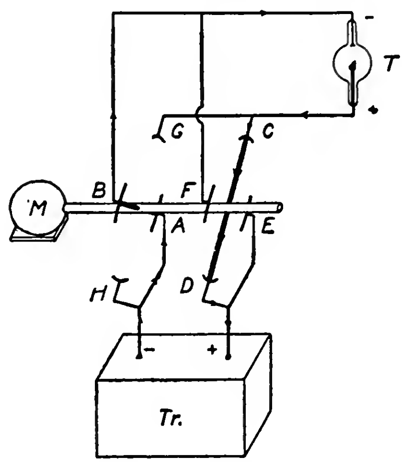

FIG. 26. Second circuit Waite & Bartlett machine—cross-arm type—two arms.

E-*F*-tube-*G*-*H*. In both cases the current takes the same direction *through* the tube.

The disc type is shown in Fig. 27. *PQ* and *RS* are two conducting sectors fastened to an insulating disc turned by the motor.

Flow is *A*-*B*-tube-*C*-*D* in one case and a quarter turn connects *D* to *B* and *C* to *A*. Meanwhile the transformer has reversed so that electrons pass from *D*-*B*-tube-*C*-*A*.

In Fig. 25 the cross-arm machine, *E* and *A*, *C* and *F*, *B* and *G* must be well insulated by barriers, or else the shaft must be unduly long. In the disc machine the diameter

must be large enough to insure insulation between the shaft and the rim and also to avoid establishing an arc between the fixed sectors along the edge of the disc.

Sparking Troubles.—Dust and moisture may impair the insulation of the barriers or disc. Keep them clean and wipe with a cloth *slightly* moistened with kerosene.

The cross-arm type must be well insulated where the arms pass through the shaft. If a break occurs there, it is not possible to patch it up. Get a new cross-arm.

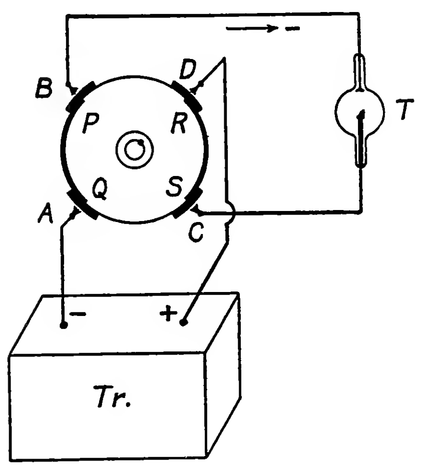

FIG. 27. Secondary circuit for disc type of rectifier.

Noise.—If a disc is out of balance or if the bearings are worn by lack of lubrication a machine will be noisy. Be sure to keep bearings well oiled. Do not accept a machine poorly balanced.

Inverse.—Inverse shows by fluorescent rings back of the target in a gas tube and by sparks across gap on low power setting on Coolidge tube. It is caused by rectifier out of position. It is assumed that the maker will *mark* the shaft of the cross-arm type or the disc in the other class with reference to the motor shaft so that one can see if slip has taken place and adjust to the proper position. If this has not been done, readjust so that the current is a maximum on a low power setting and with the tube kept constant. This is fairly easy with a Coolidge tube. One accustomed to the appearance of the arcs at the rectifier terminals can set fairly accurately by observation.

Electro Magnet and Solenoid.—Surrounding a wire while it is carrying an electric current there is always a magnetic field which will deflect a compass needle placed near it into a position as shown in Fig. 28. If now the wire be wound into a coil the magnetic action formerly distributed along the length of the wire is concentrated in the center of the coil, and if a piece of iron be inserted as a core the intensity of the field will be still further increased since the iron is much more permeable to magne-

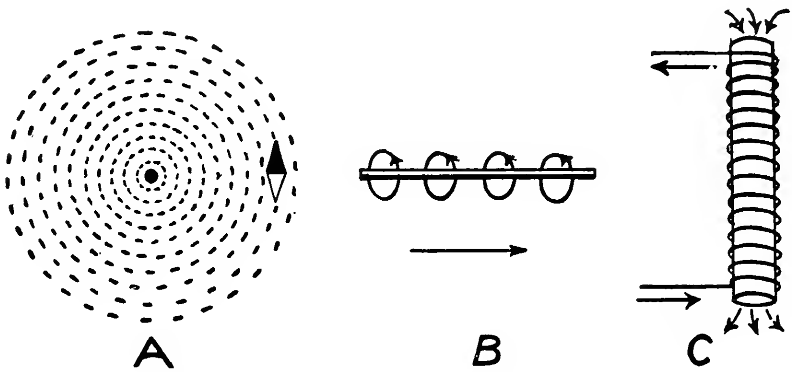

FIG. 28. Relation between an electric current and its resulting magnetic field. (a) Cross section of conductor with compass needle in field. (b) Straight portion of a conductor showing current and field. (c) Magnet coil with iron core. Greater strength than the same coil without iron core.

tism than air. The coil is a magnet only while current is actually flowing and its magnetic strength is greater the more turns of wire and the greater the current, and depends also on the dimensions and quality of the iron core and the design of the magnet as a whole. If the core is fixed and the magnetic action attracts an iron armature, as in some remote control switches, it is called simply an electro-magnet, whereas if the winding is hollow and by its magnetism sucks an iron plunger into the coil, as in the throttle control of the portable unit engine and certain remote control switches, it is called a solenoid. An

electro magnetic winding should never be connected on a voltage for which it was not designed, and a winding made for a.c. or d.c. must never be connected to the other type of current supply, as is explained in the next section.

Choke Coil.—If an alternating current be applied to an electro magnet there will be a choking effect due to the slow magnetizing of the core and the rapid alternation of the current. Less current will flow than if a corresponding voltage of direct current be applied, and the difference will depend on the properties of the magnet and the frequency of alternation. Never expect a magnet designed for d.c. to operate satisfactorily on a.c., for it will not let pass sufficient current; and *never* connect an a.-c. winding to d.-c. lines, since so much current will flow as to most likely burn out the coil immediately.

The choke coil is quite generally used instead of a rheostat as a means of control for the Coolidge filament transformer. Variation is secured by moving a piece of iron in or out of the field, the more iron in the field the more choking effect and the dimmer the filament, and the less iron the brighter the filament. Gradation of control is complete and there are no sliding contacts to cause trouble.

Protection against Surge.—The insulation of the apparatus in the primary circuit is sufficient for 220 volts, but not for high tension. If a sudden impulse or surge of electricity is set up in the primary circuit, due to a ground or short circuit of the secondary, or a spark back to the primary, the voltage in the circuit may amount to many times what it normally is.

Most of the apparatus in the primary circuit is inductively wound (electromagnetic coils with an iron core) and offers so much objection to the passage of a *sudden surge* that the path of least resistance may be through the insulation of the coils rather than through the com-

plete winding. When the insulation is punctured by the momentary pulse of high tension and a spark established, the low voltage is able to maintain this spark and build up a heavy arc, resulting in a burnout.

Protection against surges in the primary can be secured by connecting in shunt with the main transformer and motor a protective resistance, as shown in Fig. 13. This resistance is so high that it normally lets pass an insignificant amount of current, but in case of a surge the current will go through the resistance rather than break down the insulation, and the apparatus is protected.

The protective resistance may be in the form of a carbon rod, an open winding of fine resistance wire, a resistance wire baked into an enameled porcelain shell, or simplest of all, an ordinary incandescent lamp. If the more elaborate devices become broken and cannot be replaced, a lamp should be substituted rather than leave the equipment unprotected. If the lamps at hand are not of sufficient voltage, they can be connected in series; two 110-volt bulbs in series are equivalent to a 220-volt bulb.

Remote Control Switch.—Machines are frequently equipped with remote control switches or contactors which serve to make and break the heavy primary currents and to permit the use of a small, convenient operating switch. The operating push button or other device makes and breaks a small current in an auxiliary circuit, which is sufficient only to operate the magnetic switch. When the auxiliary circuit is closed, current passes through the magnet of the remote control switch and attracts an iron armature, thereby making contact and closing the main primary circuit. When the auxiliary circuit is opened the magnet ceases to attract the armature and a spring or gravity opens the contacts in the main primary.

The timing elements of most timers are delicate devices

and not able to make and break the heavy main primary current. They should be connected always in the auxiliary circuit of a remote control switch, where the current is light and will not cause damage, and they should never be inserted directly in the main primary circuit.

Line Wiring.—The line for x-ray installations should receive more careful attention than has usually been given to such important work.

The primary or low tension wiring should contain enough copper to insure that there will be no considerable voltage drop on the line even when the heaviest work is done. If a line from a supply transformer or a generator has a resistance of say .3 ohms, and one draws 50 amperes, a loss of .3 x 50 = 15 volts would result. If the original voltage was 100, the total available at the x-ray transformer would be 85 volts. On 220 volt operation this is not so serious, but more reliable operation will be attained if the wire is such that at the *highest* primary current the line drop does not exceed 3 per cent.

When a.-c. lines are used, the transformer from which power is drawn should be of ample capacity, and on d.c. the generator should have a capacity exceeding any estimated demand. Connecting a 10 kw. x-ray transformer to a 5 kw. line transformer is poor business. Fuses or circuit breakers should be conveniently placed, and all care should be exercised to avoid short circuiting or grounding the lines.

The following table shows the loss in voltage of a primary line for 50 and 100 amperes low tension current, on the assumption of a run of 100 feet between an x-ray transformer and the power transformer, giving 200 feet of line. The terminal voltage to be taken by primary and control is the difference between the line voltage and the loss. Thus, a machine drawing 100 amperes for a short exposure on a 220 volt circuit, using No. 10 wire, will have 220 —

19.9, or about 200 volts available. On 110 volt operation, 110 — 19.9 = 90 volts, making a very decided percentage drop. For this reason, machines using a large primary current are unsuited for 110 volt operation if rapid work is required.

No.	Ohms per ft.	Volts lost 200 ft. 50 Amp.	Volts lost 200 ft. 100 Amp.
00	.0000778	.778	1.5
0	.000098	.98	1.96
1	.000124	1.24	2.4
2	.000156	1.56	3.1
3	.000197	1.97	3.9
4	.000248	2.48	4.9
5	.000313	3.13	6.2
6	.000394	3.94	7.8
7	.000497	4.97	9.9
8	.000627	6.27	12.5
9	.000791	7.91	15.8
10	.000997	9.97	19.9

To compute the size of wire needed, one must know: (a) the maximum primary current in the x-ray transformer; (b) the distance from the supply transformer (or generator) to the x-ray transformer.

The *loss* in voltage due to line resistance is given by the product of *current in amperes by resistance in ohms of line wire per foot, by length of supply wires in feet.* Thus, on a 220 volt line, *if* a drop of 6 volts is permissible, the line being 200 feet long and the maximum current 60 amperes, then

$$60 \times 200 \times \text{Resistance per foot} = 6 \text{ volts}$$

$$\text{Resistance per foot} = \frac{6}{60 \times 200}, = .0005 \text{ ohms.}$$

The smallest permissible wire then is "No. 7." Better use a wire considerably larger to insure the best operation.

High Tension Wiring.—In the use of high power machines, much greater care should be taken in high tension construction than is generally the case. Three points should be carefully considered. These are: First, safety of the patient and operator; second, prevention of loss by leakage; third, avoidance of puncture of tubes.

While one might get a very unpleasant jolt from an induction coil, yet danger to life is slight as compared with transformers of like voltage. In general, a *maintained* voltage of 500 through vital portions of the body is dangerous if a current of 100 ma. or more can be delivered. A static machine, an induction coil, or a condenser may give a high initial voltage with a *brief* rush of current upon contact or grounding; this is disagreeable but usually harmless. In a power transformer which *maintains* voltage, the current continues, with possible fatal results. In most, if not all, installations the *middle* of the secondary coil of the transformer is connected to the iron case or to the "earth"; the earth is such a large reservoir that its electrical condition may be regarded as constant. The "ground" need not, and in fact should not, be completed by an actual metallic connection of transformer case to a water or gas pipe. Thus, when working at 60 kv. between the tube terminals, the voltage between the + line and the earth is + 30 kv., and between the — line to earth — 30 kv.

This divides the insulation strain on the transformer and reduces danger of sparking to the stand. If one terminal of the transformer were grounded, the full voltage would tend to pass current from the other line to anything connected to the earth. Thus, there would be a ten-

inch spark length to stand, floor, water, and gas pipes, etc. When treating at a ten-inch gap the strain is then double that in the other connection, but the line to the grounded side of the transformer is safe to touch. When using metal stands, tables, and protecting screens with the metal screens *between the tube* and the patient, they should be well grounded. The patient is then free from induced "static"

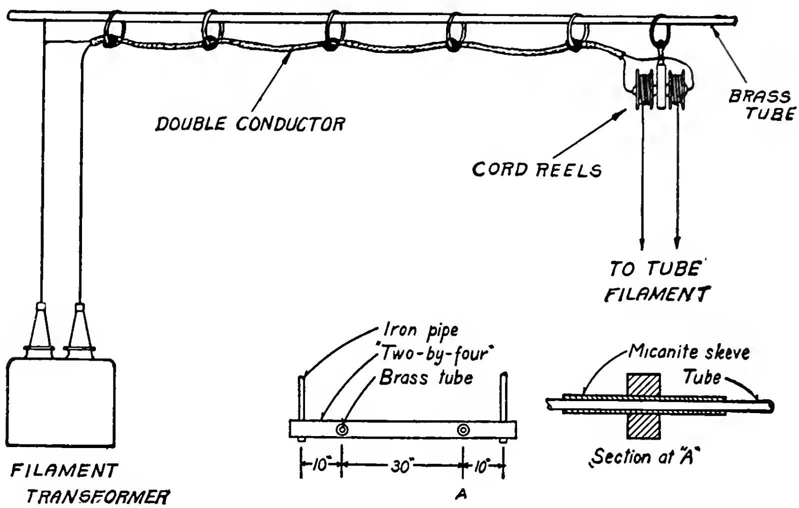

Fig. 29. Arrangement for constant resistance between filament transformer and Coolidge filament. Wire may be used instead of brass tube in the same way.

and from any discharge that may occur between the parts of the outfit. *When the patient is between the tube and the grounded metal, there is always more danger to the patient,* and corresponding care must be used.

Aside from the difficulty of preventing spark discharges and arcs, it is of great importance to prevent leakage between all parts having a high potential difference. This leakage is due to high electric stress, rendering the air conducting and giving rise to "corona." Also, many good insulators when clean and dry become conducting when

dusty and moist. High tension wires mounted on ordinary wood or on glass may be expected to leak badly.

Surface leakage is less on hard rubber and micanite than on glass. Wiping insulating surfaces with a cloth *slightly* moistened with kerosene will often greatly reduce leakage over the surface.

Corona loss is decreased by reducing the electric stress between the conductor and the surrounding air. This is accomplished by avoiding points, sharp edges, and close proximity of conductors of high potential difference. High potential overhead lines should be from 24 to 30 or more inches apart. All sharp points and corners should be avoided and small wires, especially if cloth insulated, should *not* be used. Gutta percha covered wire *without* braided covering is useful where a flexible conductor is needed. For rigid wiring and overhead lines, metal tubing not less than half inch external diameter should be used. This may be mounted by insulating rods attached to the ceiling, or as shown in Fig. 29.

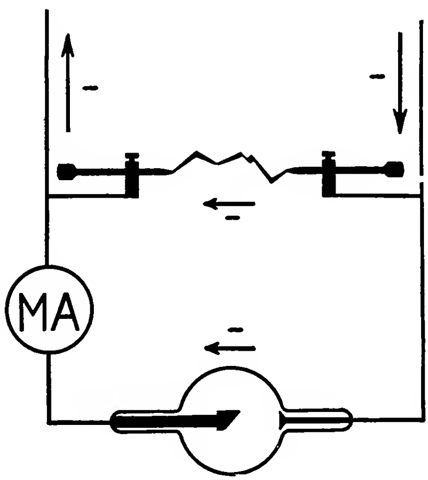

FIG. 30. The path of negative charge from line through spark gap, tube and milliammeter.

The same design can be easily adapted to inter-connecting rooms by mounting the tubing in the center of a large micanite or porcelain tube and filling the space with a good insulating wax. The insulating tube should be extended 6 to 8 inches from the wall. The rings for tube connection may carry reels if desired.

While line leakage of moderate amount may be tolerated in fluoroscopic or radiographic work, it may be of great importance in treatment. A milliammeter measures not alone the tube current but all leakage *beyond* the instrument itself. Corona between wires, spark gap corona and surface leakage together may give an error of two or three hundred per cent. We may avoid this (1) by proper design, (2) by *always* connecting the milliammeter beyond the spark gap as shown in Fig. 30. (3) Where any doubt arises check by testing with a second milliammeter connected directly to the tube.

Tracing Circuits.—The modern transformer x-ray machine is rarely characterized by simplicity of wiring or accessibility of connections. In case of trouble, or where one must connect or set up the machine without expert aid, it is well to learn to trace the circuits and to test out for breaks, etc.

While to one unaccustomed to do this, it seems very difficult, a few suggestions may help. There are only two main current paths from one supply line through the apparatus to the other line—the motor circuit and the transformer circuit. In tracing either circuit, follow a complete metallic path from one supply line through the motor or transformer back to the other supply line. Where paths divide, they must come together again further on, and one must avoid simply chasing around some loop. The main circuit in outline on all resistance controlled machines is shown in Fig. 31.

Where no attempt to bring the motor contact into correct phase is made, a reversing switch is provided, Fig. 32, which changes polarity of transformer without disturbing the motor circuit. There may be a special switch to be operated by a small current through a magnet, Fig. 33. A timer connection may be added, as in Fig. 34. Several

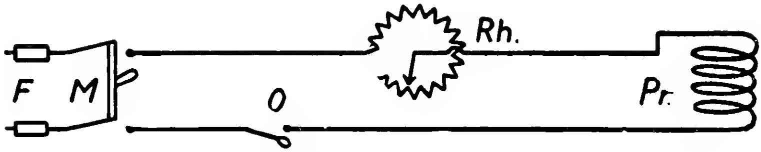

FIG. 31. Simple primary circuit, rheostat control.

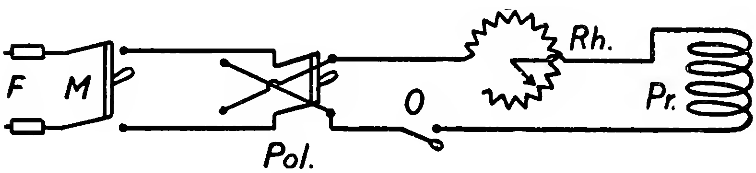

FIG. 32. Addition of reversing switch (polarity changer).

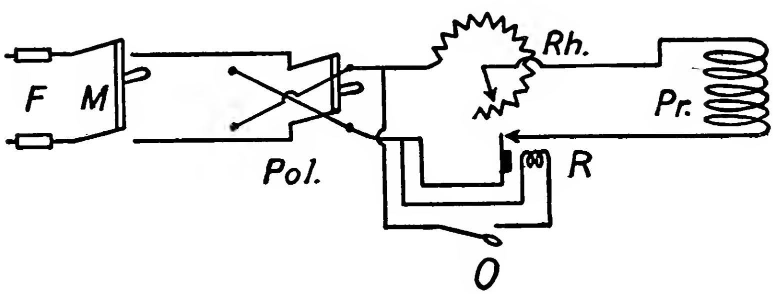

FIG. 33. Magnetic control-switch added.

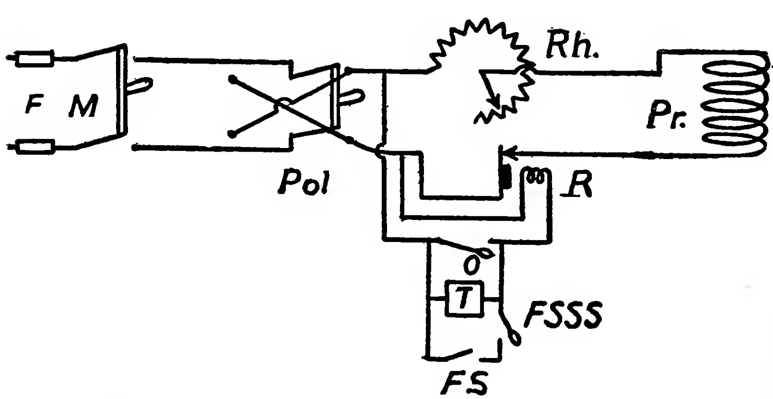

FIG. 34. Time switch and foot switch added.

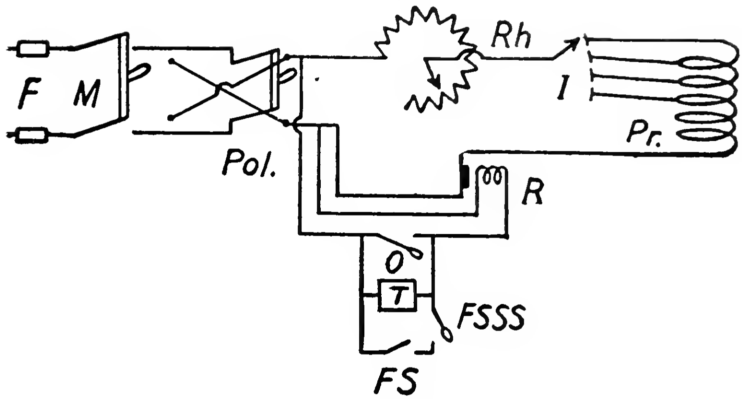

FIG. 35. Multiple taps ("Inductance taps") added.

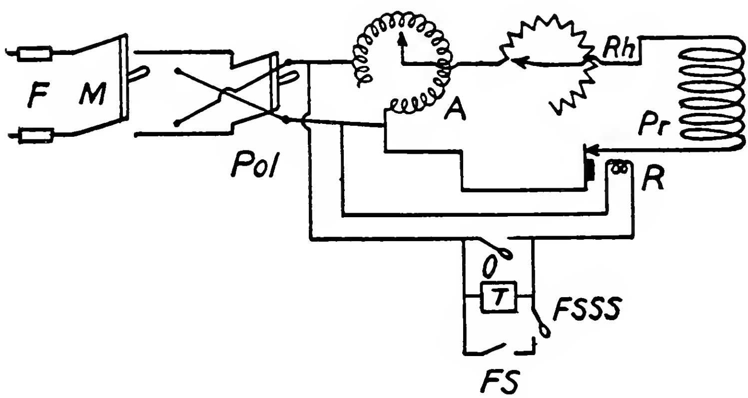

FIG. 36. Autotransformer instead of multiple primary taps.

A. Autotransformer.
C. Coolidge filament transformer
F. Fuses.
F.S. Foot Switch.
F.S.S.S. Foot switch safety switch.
G. Ground to case of transformer.
I. Inductance taps.
K.V. Kilovolt meter.
M. Main switch.
Mot. Motor.
O. Operating switch.
Pol. Polarity changer.
Pol.I. Polarity indicator.
Pr. Primary of transformer.
Prot. Protective resistance.
R. Remote control contactor.
Reg. Filament regulator.
Res. Resistance.
Rh. Rheostat.
T. Timer.

taps (inductances) may be brought out from the primary winding, Fig. 35. There may be a polarity indicator to show the way to place the reversing switch for a given tube connection. An autotransformer may be used as the control device, Fig. 36. The fundamental wiring scheme of all base hospital machines likely to be used is shown in Fig. 37. There are a considerable number of differences between the various machines but they all conform more or less to the same general scheme. Different models put out by the same manufacturer may be no more alike than the different makes. Whatever machine be used, to become familiar with the wiring will help to quickly overcome difficulties when they arise.

Locating Trouble.—Troubles in x-ray apparatus may be divided into two groups: (a) mechanical; (b) electrical.

Under mechanical, we may have worn bearings, worn or broken brushes, slip of rectifier on shaft; warping of wood, thus throwing shaft out of alignment. Care in oiling and keeping apparatus clean and dry will prevent most of these.

Under electrical troubles we have: (a) Improper connections; (b) break in conducting line; (c) loose connections; (d) failure of insulation.

To avoid (a) all wires removed from their connections should be labeled as well as the binding posts, etc., from which they were disconnected. Serious damage may be done if one attempts to operate with improper connections.

To find breaks, close switches and use test lamps, as directed in the following pages. When the lamp lights on connecting two points between which the resistance should be low, there must be a poor connection or a break.

Loose contacts are likely to cause irregular or intermittent action. Failure of insulation may cause current to

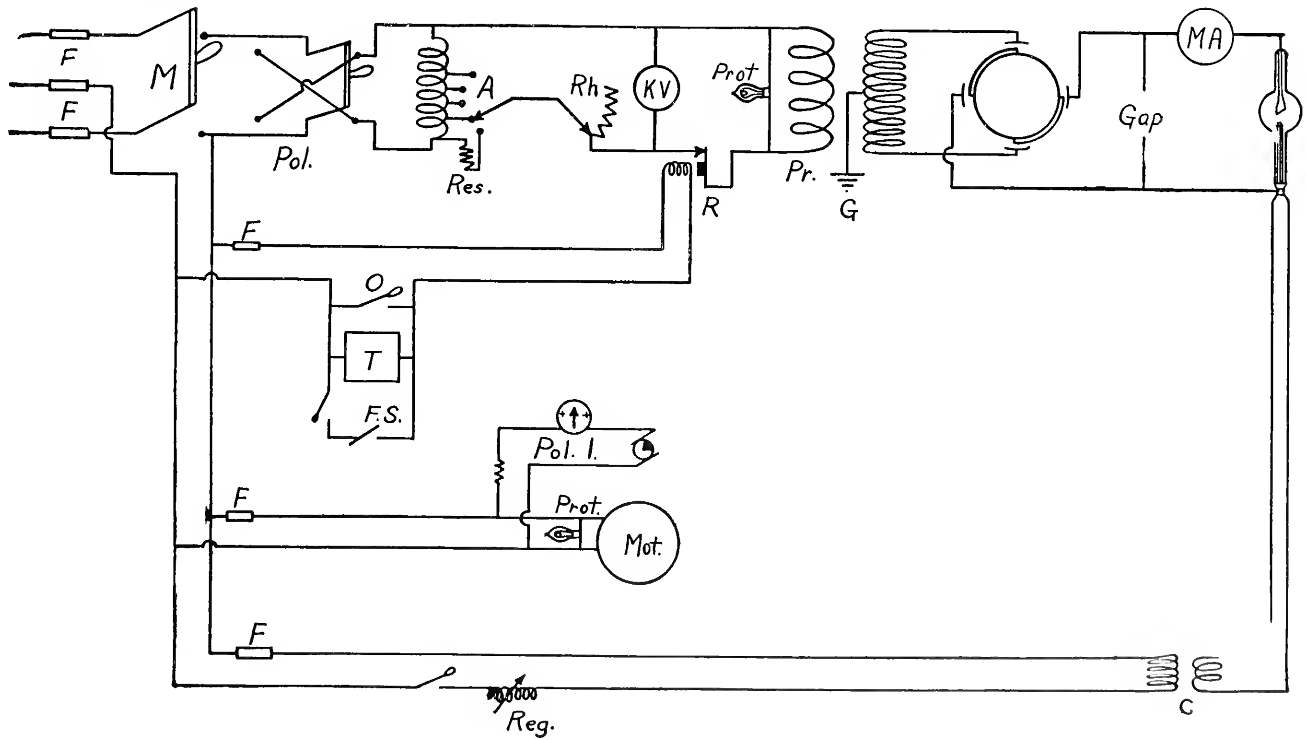

FIG. 37. Diagram of an x-ray machine, which, although it does not exactly represent any one machine, illustrates the fundamental connections of all of them. The principal low tension circuits are main primary, remote control, motor, and filament primary. Key to lettering is on page 77.

pass between two wires without going through the proper path.

If the fuse in any part of the circuit blows when only moderate power is used, open all switches and look for a short circuit; and if none is found insert a new fuse and test out on low power before attempting to continue work. Beware of the high tension line and terminals when hunting trouble on the primary or motor circuit.

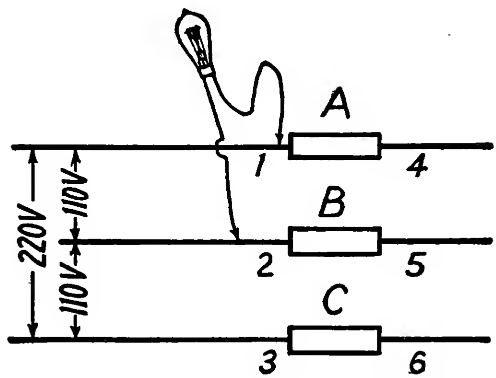

FIG. 38. Use of a lamp in trouble hunting.

Primary Circuit.—When a machine which has been operating fails to work, there must be trouble in either the supply or some part of the circuit insulation or wiring. The low tension side may be easiest tested by using an ordinary incandescent lamp of suitable voltage. Start back of the fuses on the main line, having motor and transformer switches *open.* Fig. 38.

Touch lamp terminal wires (bared ends) to bare wire at 1 and 2. If the line is "alive," a 220 volt lamp will light up to half brightness. Do the same for 2 and 3. Connect 1 to 5, and if lamp fails to light, fuse *B* is burned out. Or, if switches are closed and the lamp lights when connected to the opposite ends of a fuse, as 2 to 5, the

fuse must be burned out. Try 2 to 4 and 2 to 6; if all these connections give equal brightness to the filament, the trouble must be further along.

Close motor starting switch, and if motor does not start connect lamp across motor fuses one at a time. If a fuse is intact, it has so low a resistance that current will not pass through the lamp; if broken, the full line voltage appears at the break, and the lamp will light.

Finally, connect across the motor terminals, and if the lamp lights fully the trouble is *inside* the motor.

Follow the same general procedure in testing the transformer circuit, but *use great care to keep away from the high tension terminals;* also, be sure to set rheostat at lowest power.

If the lamp lights across the low tension terminals and no spark can be driven across a short gap between the secondary terminals, the trouble is inside the transformer and the chance of its repair by an operator is slight. If a break is near the terminals, it may sometimes be located and repaired; otherwise it must be sent to a manufacturer.

Secondary Circuit.—Outside of a break in the secondary coil or an arc to the case, the most common trouble in the secondary line is a complete or partial short circuit. This may occur in various ways:

1. In a cross arm machine, the insulation may break down between the cross conductor and the rectifier shaft.

2. In a disc machine, the disc may be dirty or carbonized, "shorting" around the periphery or to the motor shaft.

3. A high tension line may be in contact with the tube stand, a wall containing metal lath, the floor, etc.

The latter may, of course, be remedied at once by the operator.

In case of rectifier trouble, a Coolidge tube may be **run** directly on the transformer, *provided low spark gap and current is used so that the target does not get hot.* For fluoroscopic work there is no trouble in doing this, but for radiography time must be allowed between exposures for the target to cool.

Care of Tubes.—All tubes are fragile and may easily be damaged by fracture. A warm tube must not be placed on a cold support. Keep tubes free from dust and moisture. Do not allow either high tension wire to come within

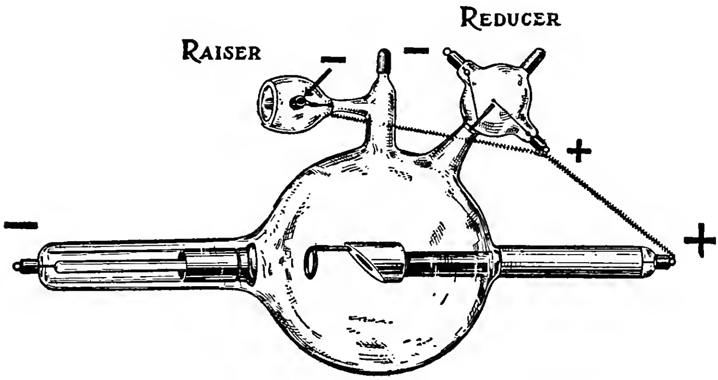

FIG. 39. Diagram showing softening and raising connections on Snook hydrogen tube.

five or six inches of the glass bulb. Always heat the filament of the Coolidge tube before attempting to pass current through it. Preserve cases or frames in which tubes are received for the return of punctured tubes or those requiring repumping. Use great care in softening gas tubes. Never soften a gas-containing tube with rheostat set for heavy radiography; use low power. If a tube is too soft, the rays emitted will not pass through the flesh. Better take more time and soften stepwise, testing after each *short* passage of current through the softener.

To soften the Snook hydrogen tube, pass through the reducer about 15 ma. five or ten seconds at a time. Re-

peat if necessary. Do not use more current; *use more time.* Always maintain polarity, as shown in Fig. 39. To harden the tube, pass through the raiser about 25 ma. (never more than 30 ma.) twenty seconds at a time. If the tube is excessively soft, disconnect spiral temporarily from + terminal of raiser. Connect anode wire to + terminal of raiser and cathode to — terminal of raiser. Run three minutes with 22 to 25 ma. Repeat if necessary. Replace spiral. Regulate tube before making exposure. It should test out at 2-inch gap and about 5 ma. The tube tends to harden a trifle during the first exposure when the tube is cold. To compensate, introduce a little more gas. Operate at 40 ma. for a medium focus tube. It will give much more service than at 45 to 50 ma. A sharp focus should be limited to 20 ma. and the time of exposure doubled. Use a broad focus tube for extremely fast exposures in making stomach and intestinal plates.

When a tube is in operation, the heat developed at the target is measured by the current x voltage. If this heat is produced at such a rate that it cannot be dissipated by conduction and radiation, the metal at the focal spot may be vaporized or melted and the tube ruined very quickly.

It is rarely necessary to do so-called flash or instantaneous work, and it can only be done at high tube cost. Properly used, a tube is capable of a large amount of work.

Do not use intermittent excitation during an exposure. In heavy work, if 60 ma. for four seconds overheats the tube at the gap needed, many operators close the switch for four separate seconds with three *intervals* of a second or more. The patient must remain at rest for seven seconds. The same exposure may be secured with 40 ma. continuously delivered for six seconds. In the latter case the danger of pitting or cracking the target is less and the

part need be held immobile for less time. This intermittent method has been suggested to overcome the tendency for voltage drop on heating gas tubes while in operation, but the allowable interval is too short to do much good.

Care of Motors.—1. All motors need oil at periods depending on the amount of use. Failure to oil may cause the bearings to wear enough to allow the armature to rub on the field supports and ruin the motor. Follow the maker's instructions, if any are given. Do not use too light an oil. An oil like 3 in 1 is good for sewing machines, but must not be used on power motors. Use real machine oil.

2. Most, if not all, motors used on x-ray machines have either slip rings or commutators, or both. Bearing on these are carbon or other conducting brushes. As the tension is low, these must have a good, even contact. Springs are provided to secure this, and if these break or get out of adjustment there will be either intermittent contact or none. The motor then either fails to start or it sparks at these bad contact points and corrodes the metal rings or commutator bars. If only slightly injured, they may be smoothed down by 00 sandpaper (not emery cloth), lubricated slightly with paraffin or *light* oil and rubbed off with a clean cloth. New brushes should be inserted *before* any serious trouble occurs. Be sure and put them in right, noting carefully how the old ones were placed.

3. Many motors have two sets of connections, one for *starting,* the other for *running.* Usually a double throw switch is used and marked for the purpose. Don't close on the running side and wait for something to happen. Don't throw over too quickly. Don't leave switch on starting position.

4. Keep motor clean and in as dry a place as circumstances permit.

5. If the motor fails to start, *open* the starting switch and test the fuse on the motor circuit; also be sure the line is "alive." If power is on and the fuse is intact, go carefully over the wiring to the motor, examine brushes, look at all external wires, and if no break is found it is fairly probable that some internal trouble has developed requiring technical motor knowledge for repair.

6. Be very sure not to connect a motor on a line for which it was not designed,—as an a.-c. motor on a d.-c. line; or a 220 volt motor on a 110 volt line, or the reverse; or an a.-c. motor designed for 60 cycles on a 40 cycle line, etc.

7. If an a.-c. motor fails to run at the right speed, do no try to operate tubes with it.

8. It is well to have the field and the armature of an x-ray motor protected from small sparks due to transient surges. Ordinary incandescent lamps in shunt serve very well for this purpose. Most machines have such protection, using either lamps, or special high resistances, or condensers.

Care of Transformers.—The attention of every roentgenologist should be called to the danger to the x-ray transformer arising from carelessness in operation. There are certain things which should never be done even though they might be done many times without damage.

1. Never operate at high applied voltage when the tube is taking no current, or on an open circuit, especially with rheostat control on high buttons. In this case the effective gap measuring the strain upon the insulation may be very much in excess of what is needed in practice.

2. High tension wires should not come in contact with or close to steam or gas pipes, electric service wires, metal ceilings or walls, metal tube stand, or the x-ray cabinet. Keep them away from things, where they belong. When

a discharge occurs from one high tension line to the earth the danger to the insulation of the transformer may be greater than in the case of a discharge between the two lines.

3. In all cases when starting up the machine test out for proper operation on low power and especially be careful not to attempt operation of any kind of tube with rectified current of wrong polarity. If, on moderate filament current and a low power setting, no current is drawn through a Coolidge tube, reverse the polarity and again test. After a machine is once up to synchronism it will very rarely change polarity while running, but it may do so in case of a momentary interruption of service or unsatisfactory line conditions. It is wise, whenever lights operating on the same power circuit as the x-ray apparatus become dim or are temporarily extinguished, to throw the machine to low power and again test for polarity.

4. Look to the oil level about every two months and record the date on a tag attached to the transformer. If the level is low, add more oil until all the coils are properly covered. Be sure to use *transformer oil* that has not been open and exposed to dirt and moisture. Wipe oil and dirt off the top of the transformer case.

5. Be sure that the transformer is adequately protected against surges by a suitable type of protective resistance.

Care of Batteries.—The only type of battery likely to be met in x-ray practice is the storage battery. This is sometimes used for portable coil work, and quite often to light the Coolidge filament. Each separate cell of a storage battery adds about two volts to the line. For any given voltage, then, half as many cells must be used as volts are needed. This voltage is independent of the size of the cells. A storage cell does not store electricity; it

uses electricity to cause a chemical change in its plates, and when it is discharged this chemical change is reversed and electric current flows from the cell. The amount of chemical change on proper charge is in proportion to the charging current and the time of flow, and is estimated in ampere-hours.

Thus, a 10 ampere-hour battery will deliver ten amperes for one hour, 1 ampere for ten hours, ½ an ampere for twenty hours, etc. Too rapid charge or discharge should be avoided because of damaging the battery.

The storage battery consists of two sets of plates, each containing a salt of lead held in some sort of small lead pockets, the whole being immersed in a solution of sulphuric acid. In a single cell, all the positive plates are joined together, likewise all the negative, and these sets must not be in contact. The negative of one cell must be joined to the positive of an adjacent one, leaving one + and one — for external connection. The ampere-hour capacity depends on the area of + and — plates per cell.

The following are the main points to be kept in mind when using storage batteries:

1. They must be charged on *direct* current.
2. The charging rate given by the maker should not be exceeded.
3. The discharge rate allowable should not be exceeded.
4. Loss of electrolyte by evaporation must be replaced by adding distilled water, rain water, or as pure water as can be had.
5. Loss of electrolyte by accidental spilling must be replaced by adding an *acid solution* of the proper density.
6. In making up an acid solution, never pour water into the acid, but pour acid slowly into the water.

7. Never let the solution get so low as to leave a portion of the plates bare.

8. Do not overcharge, nor discharge after the voltage falls below 1.8 volts per cell.

9. Do not let the battery freeze.

10. Do not let the battery stand idle for long periods. If it must be laid up, charge it fully and draw off the solution. For short periods, put a high resistance across its terminals and let it slowly discharge, and charge it up again at intervals.

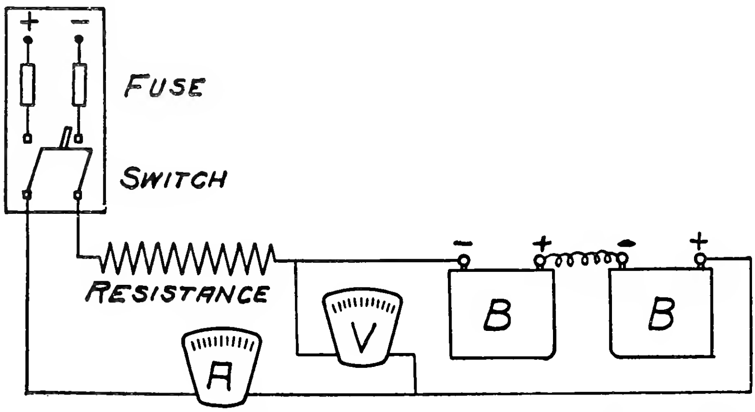

FIG. 40. Storage battery charging: *BB*—two cells in series; *V*—voltmeter; *A*—ammeter.

11. If overheated by too high current passing in or out, the active material is likely to crumble and fall to the bottom of the cell and cause a short circuit, whereby the battery discharges internally.

12. The discharge voltage falls quite rapidly after a battery is first charged, then more slowly until nearly discharged, then rapidly. When used on a Coolidge filament, which requires about four amperes, it is well to pass twelve or fifteen amperes through a suitable resistance for three or four minutes to bring the voltage down to the steady state the first time it is used after charging.

13. A small voltmeter is very useful in charging a battery, and a suitable resistance to bring the line voltage down to that required in charging should always be at hand. Either a voltmeter or a test for acid density may be used to indicate full charge.

14. Do not fail to disconnect the charging line before using on a Coolidge tube.

15. Storage cell terminals are almost sure to corrode; scrape clean when connecting.

The charging connections are shown in Fig. 40. If the battery has any charge, it will deflect the voltmeter in the same direction when discharging as when charging. Connect the voltmeter in the right way before starting to charge, and it will tell you whether you have connected to the charging line correctly. The ammeter may be omitted if one knows that the charging current is neither too large nor too small.

Emergency Provisions.—In military x-ray work it is of the utmost importance that apparatus be kept going at all times to meet the demands that are placed upon it. The roentgenologist must keep in mind the human lives dependent on him, and he must make every effort to repair, improvise, or do without whatever piece of apparatus may fail in the rush of work. There may be loss of time in securing replacement parts or repair assistance, and during this delay the plant must be maintained in operation. The following are some suggestions for emergencies.

Polarity Indicator.—This piece of apparatus may be classed as a luxury, and in case repair cannot readily be made no interruption of service is warranted. With a gas tube, polarity is readily shown by the appearance of the tube. Correct polarity results in a uniform color and inverse in a series of rings. With a Coolidge tube the milliammeter serves as a guide, for no current will flow

through the tube in the inverse direction. If the meter registers, the polarity is right. Always test on low power to avoid puncturing the tube. Spark gap may be used as an index if the meter also has failed, since on the same control setting the gap will be greater when the tube is not taking current than when it is.

In case of burnout of the resistance, sometimes included in the polarity indicator circuit, an incandescent lamp may often be substituted. Never attempt to connect up without the resistance.

Milliammeter.—In working without a milliammeter the appearance of a Coolidge tube gives no idea as to the amount of radiation produced. If the machine is on a steady power line the transformer chart may be used as an accurate means of obtaining a setting of the machine. Suppose a 5-inch gap and 40 ma. is desired, refer to the chart and find which control button must be used. Then, instead of using the chart in the customary way, set the gap for 5 inches and vary the filament temperature until the spark is barely able to break the gap. The milliamperage will now be right—40 ma.

The appearance of a gas tube is somewhat of a guide to tube current, but if an accurate chart has been made of the machine it is safer to refer to that. At what appears to to be a working setting, measure the spark gap. Then see what current corresponds to this gap on the control button used.

In working under uncertain conditions, *be sure that the spark gap is as high as it should be.* A difference in tube current will affect only the quantity of radiation; a difference in voltage not only changes the quantity but the penetration as well.

Timer.—If the timer fails, exposures may be made according to the second hand of a watch or by counting

seconds. "One thousand one, one thousand two, one thousand three," etc., is a convenient method, and a little practice will enable one to keep close pace with a stop watch.

Remote Control.—In case of failure of the remote control magnet coil or another device in its circuit the customary operating switch will be of no service. It is possible, in some instances, to wire around the remote control switch, or block it closed, and operate from an auxiliary switch in the main circuit, such as a pole-changing switch. Of course, care must be taken to *always close the switch the right way*, otherwise there is great danger of tube breakage and sparking to the patient on inverse polarity. Or, in some cases it would be more convenient to operate by holding the remote control switch closed with a stick during the exposure.

Protective Resistance.—If the shunt resistance or condensers protecting against surges become broken or unserviceable, do not leave the circuits unprotected, since a more vital element may be damaged. An incandescent lamp of proper size and voltage (usually 220 V, 16 candle power, carbon filament) connected in shunt as shown in Fig. 13 is very good protection.

Motor or Rectifier.—In case of breakage of the rectifier or burnout of the synchronous motor, work may still be done by working on *low power* and letting the Coolidge tube do its own rectifying. (If the rotary converter fails on a direct current installation and alternating current is not available, nothing can ordinarily be done.) Set the rectifier in position so there will be a minimum of sparking distance to the collector brushes, or wire across these gaps. Leave the motor switch open, or in case it must be closed to get current through the main primary and filament primary circuits, disconnect the lead wires to the motor and tape the ends to prevent short circuit. Then,

starting on low power, set the tube for a 5-inch working gap and 5 ma. All Coolidge tubes will operate self-rectifying so long as the target does not become hot enough to emit an appreciable number of electrons. Do not work at more than 5 ma. and *do not let the target heat to redness,* or the tube will no longer rectify, and will very soon be ruined.

Spark gap is not a reliable guide to working voltage in a self-rectifying tube, since the inverse voltage is higher than the working voltage. (See page 37.) The excess over working voltage depends on the resistances in circuit and the type of control. To secure a setting of 5-inch working gap and 5 ma., refer to the chart of the machine and set to 5 ma. on the proper control button. Check by seeing that the spark gap is approximately that at which the chart line crosses the vertical axis of the chart. Be sure that the working voltage is what it should be to give rays of adequate penetration. Do all radiographic work either by giving increased time or by using intensifying screens and exposing as with the bedside unit.

Autotransformer or Rheostat.—On many machines having combined control, a failure of one of these elements would merely necessitate leaving it out of circuit and controlling by the other. Broken wires or burned-out coils in a rheostat are easily wired across, but a failure in an autotransformer is a much more difficult proposition. In case it is necessary to improvise a complete new control, this may be done by building a water rheostat.

Fill a large wooden pail with water and drop into it a lead or iron plate of about 60 square inches area with wire attached, for an electrode, as in Fig. 41. Suspend securely, and so its immersion may be definitely controlled, a smaller

piece of metal as the other electrode. Immerse it slightly to correspond to the lowest power setting desired. Test it out, and add ordinary salt slowly, making sure that it is all dissolved, and testing at intervals until the desired low-power setting is reached. Pure water is a very poor conductor of electricity, and the addition of salt lowers the resistance of the solution to the desired amount. Higher powers will be secured by immersing the upper electrode deeper in the solution and lower powers by withdrawing it.

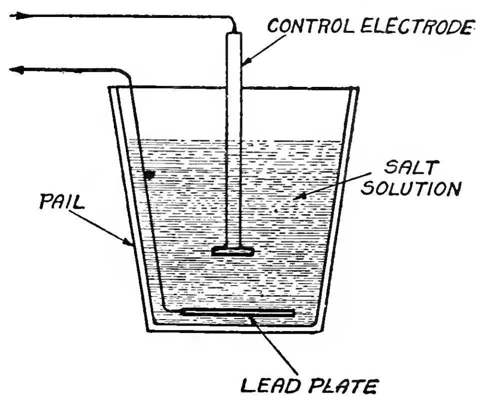

FIG. 41. Emergency rheostat for control of primary of x-ray transformer.

It may be noted that in case of failure of both rheostat and autotransformer on 220 volt machines, as a general rule we may secure reasonable operation by applying 110 volt service directly to the 220 volt connections on the transformer. Then select, when using the Coolidge tube, that current which will give a 5-inch gap and modify exposures if the current is greater or less than that usually employed.

Fuses.—In case the supply of plug or cartridge fuses runs out *never wire across the cut-out block with copper wire.* Have an ample supply of 10 ampere fuse wire on hand and include the proper amount of this in the circuit. To fuse for 30 amperes use 3 strands in parallel, for 50 amperes use 5 strands, and so on, Fig. 42. For less than ten amperes the wire may be whittled down to smaller cross section. The length of the fuse wire does not alter

the current at which it will blow, nor does the voltage of the line on which it is used.

The above suggestions cover most of the cases that are likely to occur. The resourcefulness of the roentgenologist is relied upon to cover the others and to keep his plant in operation so long as he has electric power, a transformer, and a tube. With these three essentials and a little ingenuity he should be expected to generate x-rays and do creditable work in an emergency rather than shut down and wait for assistance.

Ordering Supplies and Repairs.—Much delay and inconvenience will be avoided if care is taken to state explicitly just what is wanted and the exact quantity. The work of the supply depot must be done by people who cannot be familiar with every minute detail of x-ray equipment, and mind readers are scarce.

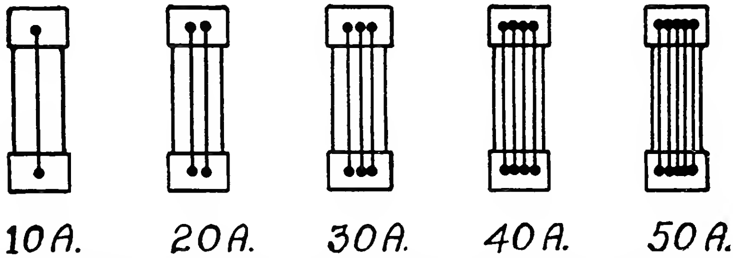

FIG. 42. Method of using 10 ampere fuse wire to secure capacity desired. It may be soldered to the brass ends of the burned out fuses.

When ordering a machine specify:

1. Type of current, a.c. or d.c.
2. The frequency of cycles, if a.c.
3. The voltage.
4. The power available in kw.
5. Gauge and length of wire needed to connect up.
6. If d.c., always specify a rotary converter and the d.-c. voltage.
7. Be sure to state that the motor, transformer and

Coolidge filament transformer when used on 154 volts or 70 volts a.c. from a rotary must operate properly.

Thus—220–volt–a.c.–60 cycle–10 kw—specifies a definite type of machine.

In ordering repair parts state the name of the apparatus, the maker, if known, and either give a drawing or such an exact description or name as to identify the piece required. Sometimes one may return a broken or defective part as a complete identification.

In case of supplies be sure to give the amount and any other information that will make your needs clearly understood. Thus an order for "an x-ray screen" is meaningless; one for a "10 x 10 inch Patterson fluoroscopic x-ray screen, mounted with lead glass," is definite.

Never fail to give complete address to which goods are to be forwarded.

No small part of what we protest against as "red tape" is made necessary by failure of individuals to convey a *clear* idea of what they desire.

When possible confine your requests to those articles specified in the supply tables.

Induction Coils.—It sometimes becomes necessary to work for a time, at least, with an induction coil. While not often used in this country one must be prepared to use it if need be abroad.

Coil Characteristics.—A good induction coil should be able to give a heavy discharge at a voltage high enough to break a 10- or 12-inch gap.

Under no circumstances must a coil be operated at high power long enough to heat the insulation, as the insulating power is much reduced at high temperatures. Each coil has its own characteristics which determine its best working conditions. These characteristics depend on the primary and secondary resistances, on the amount and

quality of iron in the core, on the number of turns in the coil, and on the mode of winding.

The most undesirable feature in coil operation for x-ray work is the unavoidable inverse which must be minimized in the use of the ordinary tube. The amount of inverse depends on the coil, the interrupter and the tube. A coil having a considerable number of primary turns and but little "magnetic leakage" gives less trouble with inverse than other types.

The direction of secondary current while the primary is increasing is opposite to that during a *decrease* of primary current. Generally it is possible to reduce primary current at a greater rate than that at which it can be built up. Hence the "break" voltage is usually higher than that at "make." The current of higher voltage is useful in the tube, but the inverse is not only ineffective for ray production but is a source of positive injury to the ordinary tube. If the make current could be caused to rise slowly enough, the resulting secondary voltage would not force current through the tube. In practice this is not possible, although the voltage giving "inverse" may be very much smaller than that giving "direct."

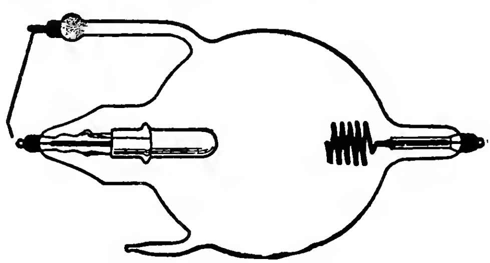

FIG. 43. Valve tube.

Valve Tubes.—In order to reduce "inverse" as far as possible, various unsymmetrical tubes, Fig. 43, have been devised; these offer much greater resistance to discharge in one direction than the other. Such valve tubes are often supplemented by a series of small spark gaps which are readily broken down by the "direct," but not by the lower voltage "inverse." These devices all reduce the energy

available for x-ray production. Fig. 44 shows a tube designed to indicate the presence of inverse. If there is no inverse, only one of the metal terminals at the gap

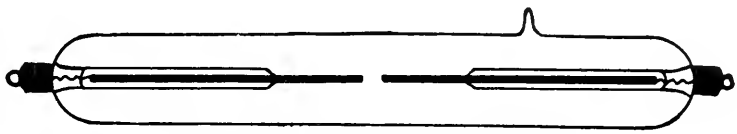

FIG. 44. Vacuum tube oscilloscope.

will glow. If both glow to the same extent, inverse current is present.

Fig. 45 shows the wiring diagram for a coil with mer-

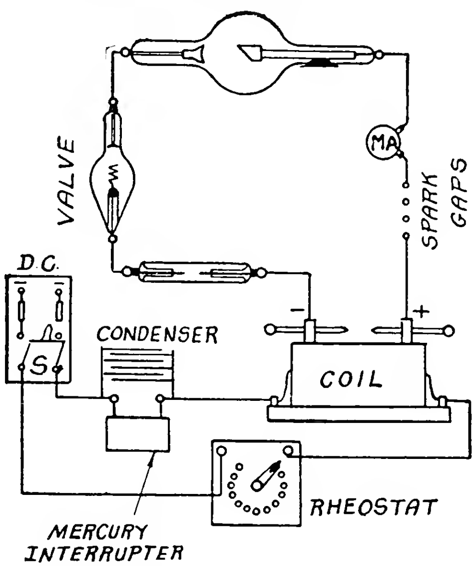

FIG. 45. Complete connection for the operation of tube with induction coil and mercury interrupter.

cury interrupter, condenser, oscilloscope, valve tube, and series spark gap. Note that the milliammeter is next to the tube.

When the spark gap is placed between the meter and the tube, leakage across the gap may make the reading

much above the current actually passed through the tube.

Interrupters.—The secondary voltage of an induction coil is the result of *change* of current in the primary. It is evident that we cannot have the primary current grow indefinitely, so we must allow it to decrease and increase alternately. The value of the secondary voltage for a given coil depends entirely on the *rate* at which the *primary current* is changed. Thus, if a current of 80 amperes should be reduced to 0 amperes in .02 seconds, the current

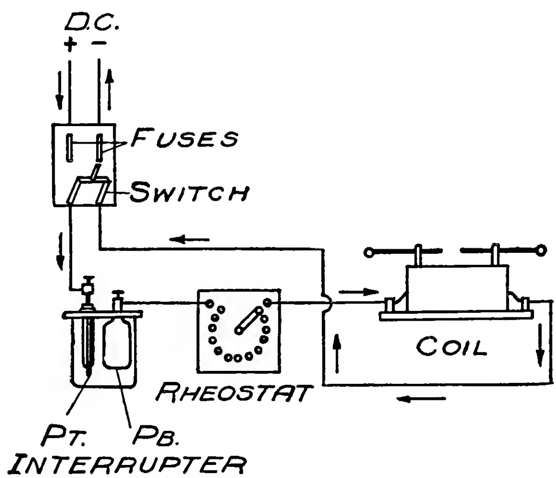

FIG. 46. Wiring for induction coil with electrolytic interrupter.

has changed at a mean rate of 4000 amperes per second. If it required .04 seconds for the same change, the rate is 2000 amperes per second. The mean secondary voltage is twice as great in the former case as in the latter.

As induction coils are intended to operate on an interrupted direct current, some device must be used to open and close the circuit. The early interrupters were of the vibrating hammer type, but these have largely been superseded by others much better adapted to x-ray work. They are still used on small outfits where large power is not drawn.

The Wehnelt Interrupter.—The Wehnelt interrupter consists of a lead and a platinum electrode immersed in a solution of sulphuric acid. The amount of platinum exposed to the solution is usually variable at will. When connected as shown in Fig. 46, the application of sufficient voltage will result in the formation of a non-conducting layer between the solution and the platinum, thus interrupting current flow. The layer is very quickly dissipated, reëstablishing current only to be again formed, etc. When

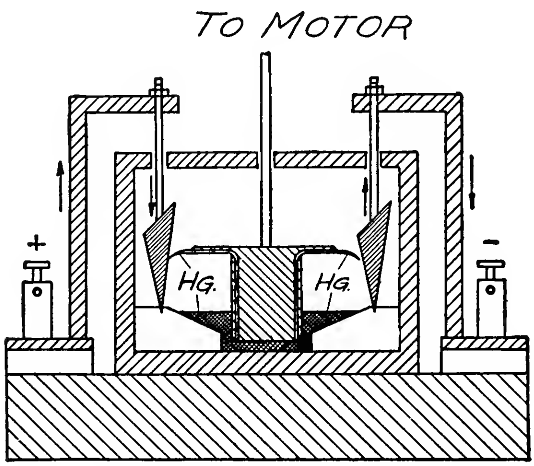

FIG. 47. Centrifugal jet mercury interrupter.

only a small amount of platinum surface is exposed, the number of interruptions per second is high and the current is small. Greater immersion lowers the number of interruptions and draws more current.

Operating Notes.—1. The solution should contain 30 to 35 per cent pure sulphuric acid. In mixing, be sure to add *small* amounts of *acid to water,* allowing the mixture to cool after each amount is added. *Never pour water into the acid.*

2. *Do not use a condenser,* as is done with the mechanical interrupter.

3. If your point or points are adjustable, use little or no resistance in series with coil and interrupter on a 110 volt circuit.

4. Your coil may not have the correct self-induction for use with a Wehnelt, at least over a wide range of frequencies of interruption. If *inverse* is prominent, try a greater amount of platinum exposed, thereby lowering the frequency of interruption.

5. Do not run too hot, and if possible enclose interrupter in a sound-proof box, or place outside.

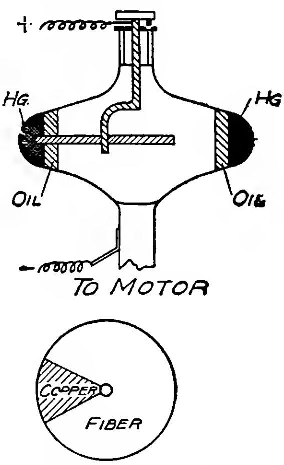

FIG. 48. "Rotax" interrupter.

6. Be sure that connections are made to the proper terminals.

7. Do not try to operate on alternating current without a rectifier. This has been done in a few instances, but is not advised.

The Mercury Interrupter.—Various forms of interrupters using mercury have been invented, and have some advantages for use with heavy coils. They allow variation in two essential particulars, viz., number of interruptions per second and relative duration of make and break. Two forms are in common use. **In the jet type,**

Fig. 47, a centrifugal pump throws small streams of mercury against V-shaped iron terminals. The motor speed determines the number of interruptions, and raising or lowering the iron decreases or increases time of flow relative to that of no current.

In the Rotax interrupter, Fig. 48, the mercury is thrown into a ring revolving with the case. An insulating disc with a small conducting sector is mounted so that it may be moved to and from the circumference. When in contact with the mercury, the disc rotates at a speed depending on the mercury speed and the amount of immersion of the disc. The latter is insulated from the case and is connected to an external binding post. The relative time of current "on" and "off" varies with the immersion of the disc in the mercury. A small amount of paraffin oil is used, forming a ring inside the mercury to prevent oxidation. A better plan, when the apparatus will permit, is to use illuminating gas in the case, which reduces contamination of the mercury and enables long periods of operation without refilling. If gas is used, a small burner should be connected to the cavity and kept burning, and the current should never be turned on until this light continues to burn, as severe explosions may result by spark ignition of an air-gas mixture. Recent forms have a safety valve to protect against explosion.

A suitable capacity must always be connected to the terminals of interrupters of this type. The amount of this capacity will vary with different inductances of the primary and to some extent with the frequency of the interruption.

Operating Notes.—Carefully read and preserve any directions furnished by the maker of the interrupter used. If none are at hand, and trouble arises, some one or more of the following may be found to account for it.

1. *No current in any position of the disc.* Look for poor contacts, either from bad brush on revolving case, loose binding posts, or broken wires. The mercury should be examined to be sure that there is enough and that the oxide does not prevent contact.

2. *Very heavy primary current and little or no secondary current or voltage.* Examine capacity to see if it is punctured; if so, renew at once. If condenser is all right, see if disc is free to turn and is not immersed too far by reason of an overcharge of mercury.

3. Be sure to keep the required amount of oil in the case, as, if there is too little it becomes carbonized by the arc and gives trouble.

4. The mercury must be kept clean. When it is dirty, oxidized, or emulsified with oil, either clean by filtering and washing or put in new mercury.

A coil in which a current is changing always develops an active opposition to the alternation of current. On an attempt to increase the current, the coil acts as an opposing generator, and when current falls the generator action reverses. This action is due to *self-induction*. The opposing voltage, when we change current at the rate of 1 ampere per second, is an important factor in behavior of the coil, and is named the *coefficient of self-induction.*

On account of self-induction, no really instantaneous change of current can take place, and the response to variable voltage will depend on this feature of the coil and on the rate at which we attempt to make current changes. Each coil is an individual in this respect, and one should find by trial the conditions under which it operates best for each purpose, and then adhere to these conditions. A little time spent in this way will save much time and annoyance later.

Tubes for Use with Coils.—The current wave from a

coil is quite different from that from a transformer. The current consists of a series of short rushes with considerable

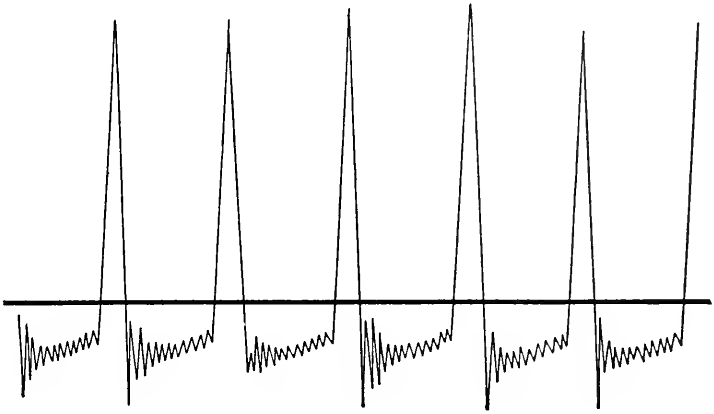

FIG. 49. Oscillogram—induction coil current with a gas mercury interrupter.

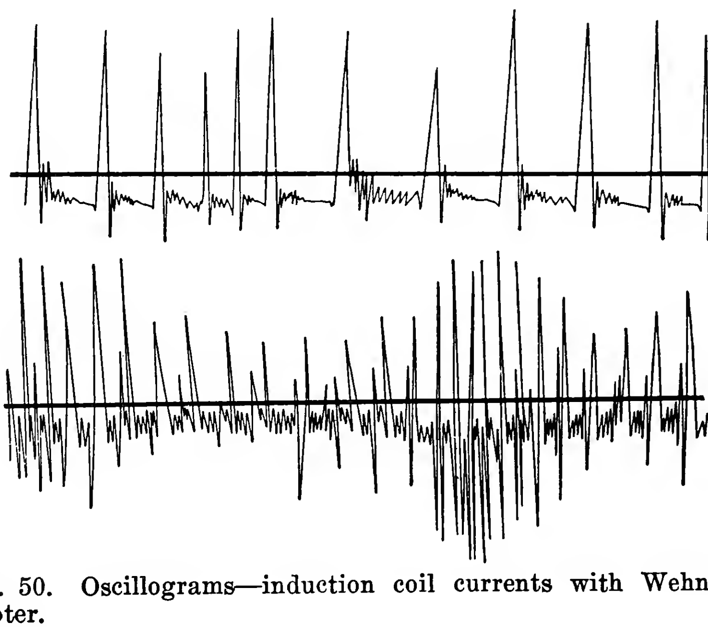

FIG. 50. Oscillograms—induction coil currents with Wehnelt interrupter.

time between each impulse. Fig. 49 shows the variations of current with time on an induction coil with a good mercury interrupter. Fig. 50, two curves with a Weh-

nelt break. Note the large amount of inverse in the latter. In order that the tube current may not lower the voltage below the required point, it is essential to have gas tubes at relatively high vacuum, or hard. Thus we must have *small* tube currents.

Readings.—Milliampere and spark gap readings are far less reliable guides for radiography when using coils than on transformers. The gap shows peak voltage which may be high but transient. As the ordinary milliammeter indicates the *difference* between direct and inverse, one may get 0 reading and yet have the tube operating.

Portable Coils.—Portable coil outfits are so varied as to make brief description impossible. Those heretofore in use were largely of the ''Tesla'' type.

The electric lighting current is stepped up to about 2000 volts by a small step-up transformer, if the supply is from an alternating current line.

If the current is direct, the circuit is made and broken by some form of vibrating interrupter, giving much the same effect in the transformer as though an alternating current was used.

The 2000 volt current from the secondary of the step-up transformer charges a condenser. The condenser is discharged through a few turns of wire wound around the outside of a secondary, consisting of a large number of turns of fine wire. The discharge of the condenser is at an enormous frequency, and high voltages of high frequency are generated by the Tesla coil.

As the current delivered by the Tesla coil is alternating, a different form of tube must be used from that for other types of x-ray generator, if best results are desired. This special tube has a valve arrangement built into it which tends to suppress one wave of the current.

Fast Work.—From what has gone before, it is clear that

the same radiographic density can be secured in a great variety of exposure times. Certainly, for the inexperienced operator high speed is inadvisable. If 3 to 10 seconds would give the most desirable exposure, an error of one second would give a fairly good plate. On power such that ½ second is best, an error of one second in judgment or execution would exceed the latitude of the plate.

The conditions for fast work are:

1. Small target-plate distance.
2. Very large current.
3. High voltage.
4. Fast plates or intensifying screens.

The disadvantage of the first is distortion and haze of outline, due to size of electron focus; of the second danger of melting the target, and difficulty in setting to proper voltage. When high voltage is used, the evening up of penetration, as well as the increase of scattering with high penetration rays, tends to give flat plates. Very fast plates and ordinary plates with screens allow little latitude of exposure. Screens also may register their own dust or surface defects.

Photographic Density and Character of Negative.—Considerable objection has been made to the use of photographic plates, films, or paper in the study of this type of radiation. Much of the adverse criticism is well founded, for the following reasons: The unaided eye is a poor judge of comparative absorption of light by a negative; only by means of comparison involving photometric apparatus can one be fairly sure of correct measurement. If an unexposed or clear portion of a negative transmits an arbitrary amount of light, Q, an area transmitting 50 per cent or half as much would be said to have an opacity of 2; and the logarithm of this opacity would be named the

density of this portion of the negative. It has been found that density determined in this way is proportional to the amount of silver reduced per unit plate area. Transmissions, opacities, and densities are related as follows:

Transmission per cent	Opacity O	Density D
100 (Clear glass)	1	0 (Log 1 = 0)
90	10/9 = 1.11	.104
80	10/8 = 1.25	.223
70	10/7 = 1.43	.358
60	10/6 = 1.66	.507
50	10/5 = 2.00	.693
40	10/4 = 2.50	.916
30	10/3 = 3.33	1.203
20	10/2 = 5.00	1.609

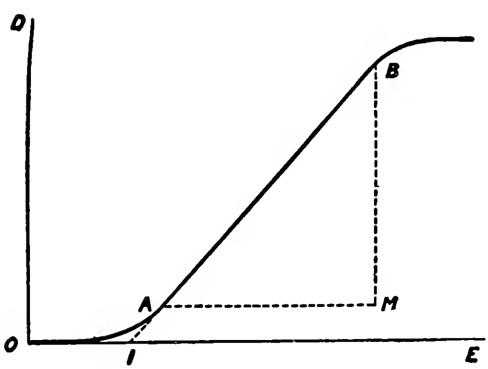

FIG. 51. The relation between exposure and density of a photographic plate. Below *A*—underexposure. Beyond *B*—overexposure. *OI*—inertia of the plate.

When the intensity and quality of radiation remain fixed, the exposure varies only with the time. Suppose that $Kt = E$ where K depends on the nature and intensity of the radiation. Plotting E and D, there remains a line approximately as shown in Fig. 51. A portion of this line AB is nearly straight; below A and above B it is curved somewhat, as shown. If AB is produced to cut the density axis at I, OI is named the *inertia* of the plate. The portion AB of the plot is the region of proper exposure. Above B the den-

sity fails to increase in proportion to exposure and is the region of over-exposure. In fact, if the exposure is carried too far, the density falls off and a reversal may occur.

The slope of the line AB or the ratio $BM/AM = \gamma$ is named the development factor: For under-development γ is small and contrast is low. For longer development, the line swings counter-clockwise on I as a pivot. The point where one should stop is a matter to be governed by experience. In ordinary photography γ ranges from .8 to 1.3; probably no accurate determination can be made of the most desirable conditions until some agreement is reached as to the best quality of negative for specific purposes.

The *inertia* of the plate is not affected by time of development. A fast plate is one where OI is small. A plate of great latitude is one where exposure difference for A and B is large. The speed of a plate is determined by the inertia OI and is expressed in arbitrary sensitometer units.

The conditions during development fix, for a given plate, a time beyond which development should not be carried on account of fog. In x-ray work, the use of high penetration on thick patients tends to fog by cross scattered radiation, and this may be noticed long before developer fog becomes troublesome.

As a means of measurement, we may utilize different portions of the same plate under different physical conditions to learn whether the radiation effects on the various portions are or are not alike. For example, if a *constant* voltage is used at constant distance, the exposure varies as the product of current and time—so that 20 ma. for 2 seconds and 40 ma. for 1 second should give equal density with equal development, provided the rise and fall of voltage be alike in the two cases.

Certain terms are in common use when negatives are described, and should be understood.

Contrast refers to the amount of difference in darkening for a small difference of exposure. Thus, if rays pass through bone and flesh, there is a variation in the amount of radiation *reaching the plate,* due to difference of absorption; when this results in a marked difference in darkening, the negative is "contrasty." Contrast depends on the nature of the plate and the development, and to a great extent on the quality of the radiation used. If the beam is too penetrating, contrast is reduced, for if rays pass through bone and flesh equally well, there would be no contrast. Too "soft" radiation will fail to get through the denser portion and will give high contrast but poor detail in thick parts. The amount of contrast to be desired will vary with the work to be done. A plate showing fine bone detail and contrast may show but little of the soft tissue.

Detail refers to the fineness of the marking of light and shade. Thus, a mastoid plate should show minute structure, or lines of light and shade should show sharp gradation or density change. Detail depends on:

1. Breadth of tube focal spot.
2. Distance of target from plate.
3. Distance of part to be radiographed from plate.
4. Complete immobilization of patient.
5. Correct exposure and development.

Exposure Table.—Many attempts have been made to work out exposure tables such that inexperienced operators can get favorable results. Without doubt the best work is done when spark gap, current, and time are chosen with reference to the individual case in hand, and any operator who cannot improve on the results secured by adhering to any single table is unfit for the work.

As a general guide in *starting* work, a uniform rather high gap may be used—say 5 inches, and a uniform target-plate distance—say 20 inches, except for chest, where 28 inches is advised. With all this understood, the average of reports from many sources gives the following table for a patient of about 150 pounds weight and a Seed x-ray plate. Some people prefer a *shorter* gap for most work [p-a head work excepted], and certainly with the ordinary solid tungsten target, medium focus Coolidge tube, better negatives result from proper exposure on a four-inch gap than on a five-inch one; this will require about 50 per cent increase in time of exposure for the same distance and current.

Part	Time: sec.
Head, A-P	12
Head, Lat.	6
Neck	3
Shoulder	3½
Elbow	1½
Wrist	1
Kidney	3—5
Bladder	3—5
Hip joint	5—7
Pelvis	5—7
Knee	2
Ankle	1½
Lumbar spine	5—6
Teeth (slow film)	4
Teeth (fast film)	1½
Chest (at 28″)	2½—4

All exposures on 5″ gap, 40 ma. 20″ distance except chest, which is at 28″.

NOTES: (a) For parts above average thickness, increase time considerably more than in proportion to increase of thickness.

(b) If it is *necessary* to work at other distances than 20″, use the following table of multiplying factors:

Distance	Time factor	Distance	Time factor
15″	.6	21″	1.1
16	.6	22	1.2
17	.7	23	1.3
18	.8	24	1.4
19	.9	25	1.6
20	1.0		

For "Diagnostic plates," reduce time by ¼. For *double coated* Eastman films use half the time.

With intensifying screens no fixed rule can be given. A reduction factor may be found for the screen used as indicated on pages 112-114.

Plates and Films.—Photographic plates and films consist of a thin layer of gelatin containing a salt of silver and spread on glass or celluloid. Light and x-rays cause a change in the silver salt such that suitable chemicals, called developers, act on the portions that have received the radiation, changing the silver compound to metallic silver, and thus rendering those portions more or less opaque to light. The opacity produced will depend on the amount of radiant action, on the sensitiveness of the emulsion, and on the development. Those portions receiving much light or x-rays, when fully developed, may be quite opaque; other portions may be entirely or nearly transparent.

After development the plate is washed and placed in a "fixing" bath which removes the unused silver salt, as shown by the disappearance of the cream color of the emulsion, rendering the parts not radiated and developed transparent.

All plates sensitive to x-rays are also sensitive to ordinary light and hence they must be entirely protected from ordinary white light until finished.

The emulsion is an example of unstable chemical structure and may be injured by (1) moisture, (2) high temperature, (3) contact with other material, (4) exposure to light or x-rays, (5) bending. Plates should be kept in the original boxes, on edge, in a cool dry room, well protected from x-rays. No more plates should be put up in envelopes than are likely to be used in the next two or three days.

Filling Envelopes and Cassettes.—X-ray plates are used either in envelopes or in plate-holders, called cassettes. It is quite essential that in regular work the emulsion side should be toward the patient. To insure this when using envelopes, arrange the envelopes to be filled before darkening the room. Put black and yellow envelopes in alternation with the end flaps down, insert plate with emulsion side down, i. e., so that the flap will fold over the *back* of the plate; then insert the flap end first in the yellow envelope with the emulsion down, so that the flap of the outer envelope also folds over the back. Then place the smooth side of the envelope toward the target. A soft brush is useful to remove dust from plates and cassettes.

In using cassettes *without screens, put the emulsion side down.* This side can be determined by sighting across the surface, as it appears dull as compared with the glass side, or touching the tongue to the extreme corner of the plate—the emulsion side will be slightly sticky. Form the habit of closing partly empty plate boxes *at once* after filling envelopes or cassettes.

Attention is called here to the new double-coated film which is used to considerable extent. In this case there is no difference in the two sides of the film and no at-

tention need be paid in placing it in the special holders provided. It should be borne in mind, however, that these films must be handled with great care. Finger prints are much more likely to show and both sides of the emulsion must be protected from moisture and scratches. Great care must also be taken not to wrinkle, bend or twist these films before exposure. For this reason it is undesirable to attempt to use them in the ordinary black or yellow envelopes usually supplied. They should be used in cassettes or in the special holder furnished for the purpose.

Intensifying Screens.—When using intensifying screens the usual practice in this country is to allow the rays to pass *through the glass* to the emulsion and then to the screen surface. Consequently the negative, when viewed with the emulsion side toward the eye, is *reversed* as to *right* and *left* as compared with the usual plate. The screen should be firmly fixed to the back of the cassette and should be kept *scrupulously* clean; wipe off dust with a *clean* cloth, and never touch the surface with wet or greasy fingers. *Insert cleaned plate with emulsion side up,* and be sure that the springs press the screen firmly against the plate. On account of the variable x-ray opacity of the glass at present in use, screen work with plates is rather uncertain. Be sure to keep screen clean by not letting it get wet, dirty, or dusty.

It is quite impossible to be sure of the speed of the various screens in actual use, inasmuch as this depends on so many conditions, such as amount of use, and the general care which has been exercised in handling, as well as their initial speed.

In order that the proper exposure may be given it is well to determine the multiplying factor by which the screen increases the normal speed of the plate. This may be easily done by the use of a film of proper size in the screen

holder, exposed at the same time with one in an ordinary envelope or container laid on top of the screen. This envelope should be cross-ruled with lines approximately ½ inch apart, and a heavy sheet of lead placed to cover all except one end division, being sure that film occupies this division. Make a very brief exposure at low power and considerable distance, using a timer, if one is available, and leaving the tube, machine, timer and distance unchanged; slide the sheet of lead back, leaving two divisions exposed; and repeat the exposure. Do this for all of the film and develop both films at the same time and in the same developer.

It will be evident that if there were 15 divisions, the one which was exposed first received 15 exposures, the next 14, etc. The last may be numbered 1, the next 2, etc. If it should be found that the film in the envelope, and not affected by the intensifying screen, required 12 of these exposures to give the same blackening as number one, with the intensifying screen, it is clear that 1/12 of the time required with no screen should be used. This procedure is somewhat more reliable if exposures can be through a rectangular block of paraffin, as the speed of some screens seems to vary considerably according to the filtration which the rays have received before reaching the emulsion. Fig. 52 shows such a pair of films for a particular screen. After the determination of the speed, it should be marked on the cassette so as to be available during use.

Care in Handling Plates and Films.—In all cases, plates and films must be kept well protected by lead when in the x-ray room. A good lead-lined box on casters is very useful for this purpose, and where much work is done, one for exposed and another for unexposed plates should be pro-

vided, or a partition plainly marked "EXPOSED" and "UNEXPOSED," dividing a single box may be used.

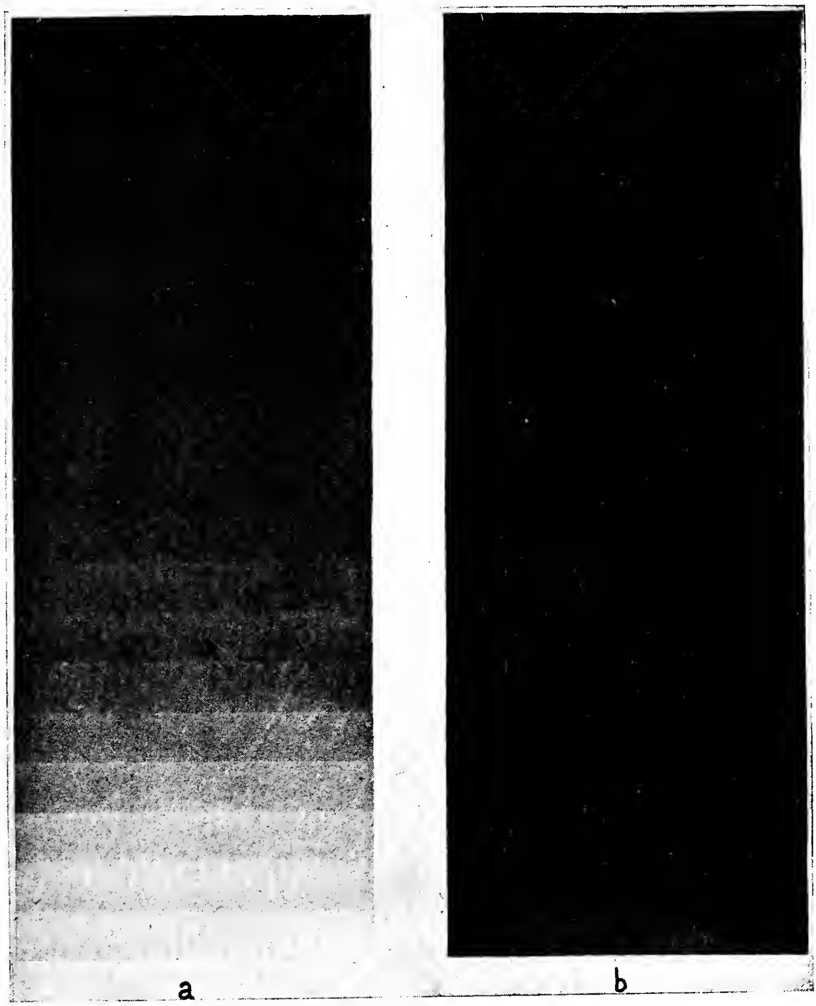

FIG. 52. Gradation due to successive equal exposures with and without intensifying screen, *a,* without screen, *b,* with screen.

The following cautions may be given to those unfamiliar with darkroom work:

1. Never handle plates or films with wet or greasy fin-

gers, either before or after exposure. Marks and streaks are sure to result, even if the emulsion is not destroyed.

2. Learn to handle plates without touching the emulsion side, even with dry fingers.

3. Mix all solutions according to instructions and see that chemicals are actually *dissolved.*

4. Keep all trays *clean,* and do not use insufficient or too old developer; stains are hard to remove, and the cost in time and money is excessive if it is attempted.

5. In tray development, be sure that the developer covers the entire plate at once. Tilt the tray slightly on inserting the plate, and tilt the tray in several directions to ensure complete wetting of the film as soon as possible. Keep tray in motion during development.

6. Do not examine the plate by removing it from the developer until the minimum time for full development on normal exposure has elapsed.

7. Do not try to develop several plates in a tray at one time if they overlap.

8. Wash negatives well on removing from the developer, before placing in the fixing bath.

9. Leave negatives in the fixer for some minutes *after* they *seem* to be fully cleared; then wash thoroughly, in running water if possible.

10. Do not use the same trays for hypo and for development. Mark hypo trays and keep them well away from developer. A little hypo in the developer is fatal.

11. Keep negatives in a dust-free atmosphere and in one location and position until dry.

12. When the developer is not in use, keep in *tightly* closed containers. Glass fruit jars with rubbers are as good as anything for small amounts. Use a close-fitting float in tank.

13. Don't try all the developing formulæ you can find;

take one advised for the plate you use, and learn to use it.

14. Don't fix in plain hypo in warm weather. Plates will frill if you do.

Tank Development.—In tank development, the plate is placed, while dry, in a special frame or holder and hung vertically in the tank containing the developer. This method is desirable when much work is done. With strong developer, stirring by moving the holders will prevent vertical streaks.

Temperature.—The action of the developer varies greatly with changes in temperature. Between 60° F. (16° C.) and 70° F. (22° C.) is best. Hot developer works *fast* and is likely to fog the plate. Cold developer is slow and may not give anything on a normal exposure. Do *not* cool developer by *adding* ice or ice water, as this dilutes the solution. When using tanks, cold or ice water may flow or stand around the developer tank until a proper temperature is reached, or put ice in a fruit jar and immerse jar in developer.

Concentration.—If more water is added to a normal developer, slower action will result. This is sometimes advised in tank development, and with screen plates, but is not necessary if the developer is stirred occasionally.

Plate Defects.—Plates are sometimes defective, due to faults or accidents in manufacture, but in most cases of complaint the trouble is due to improper treatment after leaving the factory. If one is sure of proper exposure, development, fixation and washing, and still finds streaks, spots, bubbles, or bad color, the plates may be blamed. Much trouble is traced to the materials used at present, and in all cases of doubt check plates should be made. Defects are not likely to appear on the same region in both negatives. Looking across the negative at any unevenly illuminated surface will often show whether a spot

is due to a defect in the glass or to something on the emulsion surface.

Examining Negatives.—When it can be avoided, plates ought not to be examined until dry. If they must be used while wet, care is needed to avoid heating the gelatin or it will melt and completely ruin the negative. A well-diffused illumination is very desirable; it should be well under control so as to give a strong light for dark negatives and a much weaker one for thin ones. Ground or opalescent glass is not needed if a dull white surface is illuminated and the plates are viewed by light reflected from it. Fig. 53 shows a useful type of illuminator.

Developer Action.—The action of developer on an exposed plate is rather a complicated matter. For the present purpose we may omit discussion further than to say that with any active developing agent a suitable amount of alkali is indispensable. Do not vary the proportion shown in reliable and tested formulæ, at least in routine work. Development at any given depth below the surface of the emulsion can only take place when the active developing solution has reached that point in sufficient amount to cause the change required. Hence, dilute or partly exhausted developer requires more time. Prolonged action of developer on the emulsion will cause a darkening even with little or no exposure, and too strong developer will over-develop the outer layers before the deeper ones are affected. Plates exposed to x-rays are developable through the entire depth of emulsion, while light only affects the outer layer. Hence, if fog can be avoided, x-ray plates will increase in density with longer development to a greater extent than will negatives exposed to light. The action of potassium bromide restrains or delays development at the surface and tends to keep the "whites" clear. All developers are absorbers of oxygen and are useless when

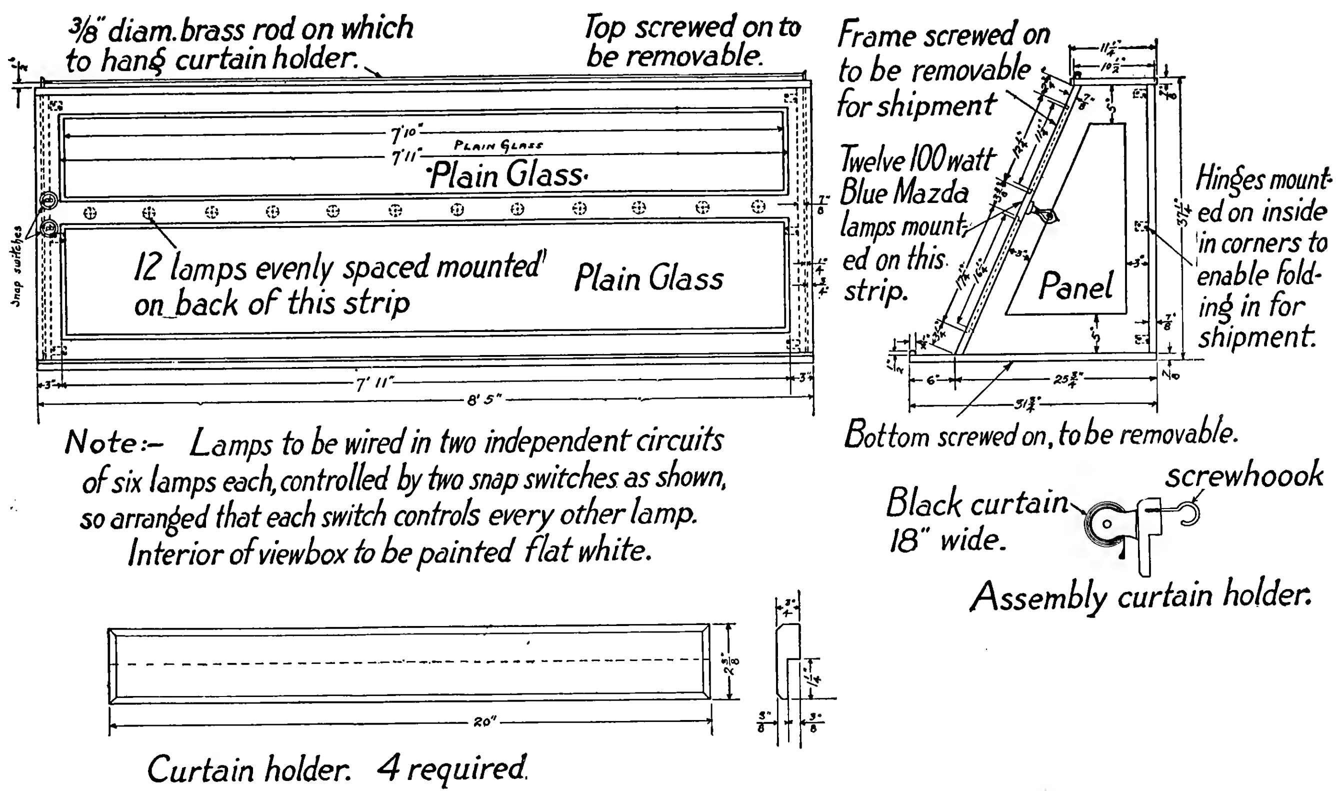

FIG. 53. Viewing screen. This viewing screen can be made in any desired length. It can be mounted on a plate-filing cabinet or on saw horse. Ventilator holes are provided to prevent excessive heat. It is so constructed that it can be readily knocked down for shipment.

they no longer absorb this gas. For this reason, they ought to be protected from air when not in use.

"Hypo" or Fixing.—The purpose of fixation is the removal of all unreduced silver, leaving the small specks of metallic silver suspended in the gelatin film. Any unreduced silver left in the gelatin will sooner or later discolor and ruin the negative. By using acid and alum, the clearing is improved and the film of gelatin hardened. "Hypo" must be *thoroughly* removed by washing half an hour to one hour in running water, so that hypo crystals will not form in the gelatin, ruining the negative. If the bath is too acid a rash will appear on the surface of the gelatin. The acid should be partly neutralized by the addition of sodium carbonate. If the bath appears milky, it generally lacks acid and can be cleared by the addition of acetic acid.

Fog.—It is extremely important for every roentgenologist to realize the full effect of fog produced on the negative in development. This fog is the result of chemical action and is always produced to a certain extent. It is not uniformly distributed over the plate in any case, and is related to a certain extent to the exposure at the points where it shows. It has, always, the effect of blotting out the finer details. In a properly exposed and developed plate these finer details show as light areas against a slightly darkened background, as, for example, in the case of a mastoid plate.

As soon as fog is produced to such an extent that these clear white lines become smoky, contrast with the slightly darker background and adjacent areas may be entirely lost. Fog will always be produced if the developer is too warm, if improperly mixed, or if the time of development is too long. The only way to avoid it for a given plate is to use a proper concentration of the developer, a proper tem-

perature, and such an exposure as will enable complete development to be made before fogging action becomes effective.

The roentgenologist should invariably remember that a proper distribution of shadows on his plate or fluoroscopic screen furnishes the only physical basis for diagnostic use of his radiation, and to avoid the necessity of passing upon indefinite and unsatisfactory plates it is just as essential to pay attention to the darkroom conditions as it is to consider proper position and exposure. The diagnoses made on the basis of shadows that are so faint as to be invisible to the majority of observers introduce a very considerable element of imagination, and are relatively unsafe even for those who claim successful results on such a basis.

Developing Formulæ.—Most x-ray operators had been using a hydrochinon-metol developer prior to the shortage of metol. Certain substitutes for metol have been marketed of more or less value. The following formulæ have been found fairly good in practice:

Hydrochinone—

Water (warm)	1	gal.	5	gal.
Sodium sulphite (dry) ..	8	oz.	40	oz.
Hydrochinone	1½	"	7½	"
Sodium carbonate (dry)	8	"	40	"
Pot. bromide	1	dr.	5	dr.

Mix in order named.

Good for tank development.

Elon-Hydrochinone—

(Dissolve these chemicals in order named:)

Water	20	oz.
Elon	20	grs.
Sulphite of soda (dry)	1	oz.
Hydrochinone	80	grs.

Carbonate of soda (dry)	1 oz.
Potassium bromide	8 grs.

Good for tank development.

Edinol-Hydrochinone—

Solution A

Boiling distilled water	32 oz.
Sodium sulphite (dry)	6 oz.
Edinol	5 dr.
Hydrochinone	1 oz.
Potassium bromide	6 dr.

Solution B

Water	32 oz.
Potassium carbonate	2 oz.

Use one ounce of Solution A, one ounce of Solution B and two ounces of water. Develop 6 to 9 minutes.

Good for tray development.

Metabisulphite-Hydrochinone.—A professional photographer doing considerable x-ray development recommends the following developer as very satisfactory for general work:

Mix in order named.

Solution A

Water	200 oz.
Hydrochinone	4 oz.
Potassium metabisulphite	10 gr.
Potassium bromide	50 grs.

Solution B

Water	200 oz.
Sodium sulphite	1¼ lbs.
Caustic soda	2¼ oz.

These solutions keep well in stock. For use, mix in equal parts.

Fixing Bath Formulæ.—An acid hypo fixing bath may be prepared as follows:

Water	64 oz.
Hypo	16 oz.

When *fully dissolved* add the following hardening solution:

Water	5 oz.
Sulphite of soda	1 oz.
Acetic acid (28% pure)	3 oz.
Powdered alum	1 oz.

If preferred, 1 ounce of citric acid may be substituted for acetic.

This bath may be made up at any time in advance and may be used so long as it retains its strength, or is not sufficiently discolored by developer carried into it to stain the negatives.

Chrome Alum Fixing Bath.—This bath has good keeping qualities, fixes clean and remains clear after long continued use.

A

Pure water	96 oz.
Hypo	2 lbs.
Sulphite of soda	2 oz.

B

Pure water	32 oz.
Chrome alum	2 oz.
Sulphuric acid, C. P.	¼ oz.

Mix chemicals in order named.

When dissolved, slowly pour B into A while stirring rapidly.

Notes on Fixing.—Hypo is cheaper than spoiled plates. Use plenty and renew often. Wash all plates very thoroughly to remove hypo.

Do not strengthen an old weak hypo bath. Throw it away and make a new one. It may fix, but it is sure to spoil plates sooner or later.

Failure to wash off developer will quickly spoil a fixing bath.

Stained plates are usually due to one or more of the following causes:

Too warm developer.

Too long development of under-exposed plates.

Exhausted hypo bath.

Lack of acidity of the hypo bath.

Reducing Dense Negatives—

Solution No. 1

Water	16 oz.
Potassium ferricyanide	1 oz.

Solution No. 2

Water	16 oz.
Hypo	1 oz.

Place plate in Solution No. 2 sufficient to cover it, then add a small quantity of No. 1, and watch it carefully. If it reduces too slowly, add more of No. 1. If only too dense in places, apply the solution carefully with a brush or tuft of cotton.

Wash in running water at least a half hour after reducing.

Note.—Make negative properly and avoid reduction.

Darkroom.—The first consideration in a darkroom is the complete exclusion of *ordinary* light. All windows, cracks, knot holes, key holes, etc., must be stopped by opaque material. If possible, an entrance by corridor or winding way should be used. If a door is used it should fasten on the *inside,* so that no one can open it at an inopportune time.

The usual emulsion on x-ray plates is quite insensitive to red or orange-red light. A very small intensity of blue or white light will ruin a plate. The quality of light, not the amount, is what must be considered, and enough of a safe light may be used to see clearly what one is doing without danger of fogging a plate, if the operator is not too slow. The inner walls of the room should be painted red or orange, not black. A ruby 20-watt lamp, four or five feet above the working shelf with a translucent shade below it covered with postoffice paper, will give a diffuse illumination of the room very desirable for

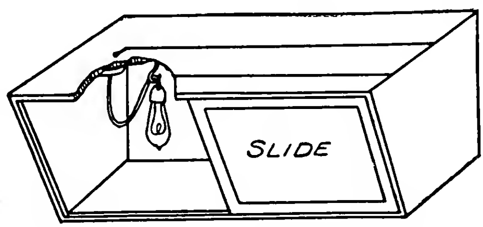

Fig. 54. Simple arrangement of light for developing. The slide contains a white and a ruby glass with yellow (P.O.) paper between. A clear lamp is used.

work. Test the light by placing an opaque object on a small plate. Expose on the shelf for two minutes and develop full time; if not fogged, the light is safe for that make of plate. If one desires to time development by looking *through* the plate, an arrangement as shown in Fig. 54 or one as sold by some dealers is desirable. By using a flexible cord, the lamp in Fig. 54 may be hung outside after the box is opened and serve as the source to be used when no plates are exposed to light.

Arrangement.—Darkrooms may be quite elaborate and yet be very inconvenient. A simple arrangement for a small outfit is shown in Fig. 55. No doors are needed in this case.

Fixing bath and supplies are to be kept apart from de-

veloper and developing supplies. A plain open shelf is used in filling envelopes, etc. Cassettes, intensifying screens, and envelopes may be kept in suitable compartments below. Plates in small amounts may be kept in compartments above this shelf. An inexpensive arrangement serving all

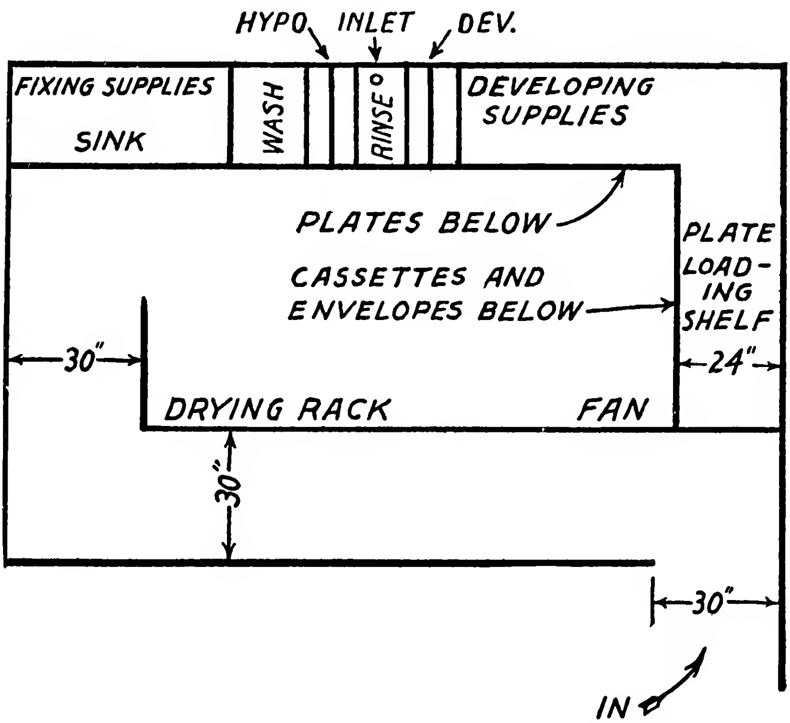

FIG. 55. A convenient darkroom arrangement.

needs is shown in Fig. 56 for holding developer tank, fixing tank, and also serving as a washing tank. For a permanent installation the tank may be lead-lined, but for a semipermanent wooden tank a heavy coating of water and chemical-proof paint will suffice. In warm weather, use ice to cool bath, and do not dilute developer.

Ventilation.—Good ventilation is essential in a darkroom, not alone to increase the efficiency of the operator,

but because a close, musty atmosphere is bad for the sensitive emulsion. When a new room is designed, the matter is quite simple, but when any old closet is regarded as good

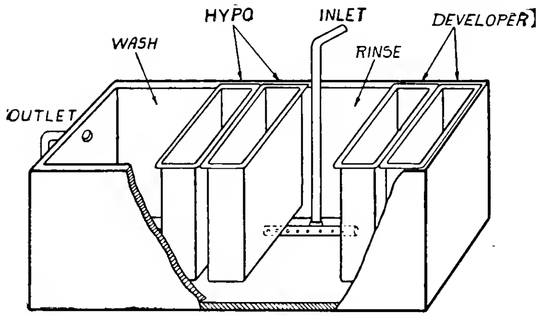

FIG. 56. Wooden tank to permit circulation of water around developer and fixer, provides for rinsing and washing films or plates at same temperature throughout.

enough for a darkroom it is quite a different matter. The important point to be kept in mind is that air must be let

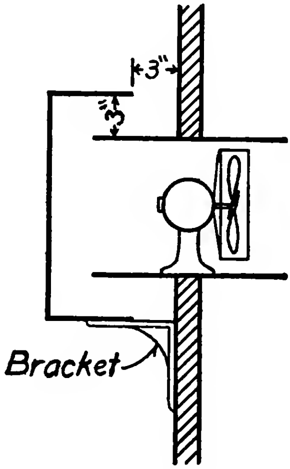

FIG. 57. Simple ventilator for darkroom. All inner surfaces to be painted red or black.

in and out, but light must be excluded. Where an electric fan can be used, it is easy to accomplish this result. Fig. 57 shows one way. The fan is placed in a box, open at each

end, inserted through the wall. A second box is placed inside the room, as shown, and all surfaces are painted a flat black. Air has free passage, and light is entirely excluded. A similar arrangement can be used in a window, either with or without the fan.

Humidity.—Basement darkrooms are often very damp in summer and very hot in winter. The best work cannot be expected under these conditions. If such must be used, it is best to keep unused plates elsewhere.

Care of Utensils.—Absolute cleanliness is essential in darkroom work. Trays not in use are best kept filled with water. Be sure that no acid gets into the developer. Do not use developer or fixing tanks painted inside with any kind of water-proof paint.

Supplies.—Be careful to keep all containers labeled, so that no mistakes are likely to be made. Keep hypo and acids away from developer material. Keep chemicals protected from moisture. Remember that twice the weight of crystals must be used as in case of "dry" materials.

Marking Negatives.—Where a large amount of radiographic work is done, a well-organized record system is indispensable. In all cases the record should show in some way on the negative, and that record must be put on *before* the plate is developed. Lead numbers may be used, and if this is done the number used and the name of the patient must *be entered on a suitable card or book at the time the exposure is made.*

If numbers are not used, a slip showing the name of the patient must be attached to the cassette or envelope, and the darkroom operator should always write the name with a soft pencil on one corner of the emulsion *before* development.

In using double-coated film care should be taken to mark right and left, as one cannot tell how the film was placed.

The X-Ray Negative.—The conditions which determine the distribution of shadows on an x-ray negative are extremely complex and vary with the physical condition, age, and weight of the patient even without any reference to pathological conditions. If there were no material between the target and the photographic emulsion, there would result, upon exposure and development, simply a uniform blackening of the plate. The introduction of material in the path of the radiation between the target and the plate results in absorption and scattering, with the result that portions of the emulsion are protected from the radiation, the resulting shadow showing as a white or lighter area by transmitted light through the negative. The amount of radiation failing to reach any area of the plate as compared with that reaching the surface of the obstructing body depends upon two things: first upon the relative physical density of the material traversed as compared with its immediate surroundings and, second, upon the distance in this material of greater or lesser density actually traversed by the rays. As an illustration, the shadow cast by a thin, flat bone, placed with its surface parallel to the plate will show little contrast as compared with the shadow of the surrounding flesh, whereas, if placed on edge, increasing the path traversed in the bone, there will be marked contrast.

In traversing the human body radiation passes through an aggregate made up of portions of decidedly different densities. Each of these portions absorbs the radiation in an amount depending both on its density and thickness. When we further take into account the physical nature of the action of the photographic plate and the different absorbability of the radiation under different conditions of tube, we may easily recognize the reason for the variety of negatives which it is possible to secure of

the same anatomical region. Inasmuch as our diagnostic information must be acquired from a study of these areas, we must not forget that pathological conditions are liable to be inferred if based upon doubtful or imperfect data, and while we can not at present lay down complete rules for the guidance of the roentgenologist it is undoubtedly true that for each individual area there is a combination of factors of exposure, penetration, development, and position, that would give the best diagnostic plate.

Consider the effect of varying (1) the quality of the x-ray beam, (2) the time of exposure when making a negative of any particular region. Assuming that we have proper development of the plate after exposure, we may note that if the tube has a small equivalent gap the majority of the radiation will be absorbed completely by even thin and non-dense portions of the patient, and that the exposure in order to have any effect on the plate must be prolonged. For example, in the case of the hand, such a tube with proper exposure may bring out wrinkles or folds in the flesh, finger nails, and a very slight infiltration in the soft tissues, and only by prolonged exposure can even a moderate definition of bones be observed. When this is done the parts of the negative covered by soft tissue are greatly overexposed. If the spark gap is too small nothing but a shadow of the hand such as would be cast by ordinary light will be observed. As we change the spark gap with a suitable time of exposure we can secure quite different qualities of negative and, with a moderate gap and exposure, fair details in the bone and the soft tissue may be observed, but, with longer exposure, portions of the plate beneath the thinner or softer regions still become overexposed, giving, on development, complete blackness without details. At the same time the outlines of the thicker portions and of the

bones may stand out very clearly, giving almost the appearance of a skeleton.

If the spark gap is made too high the radiation reaching the plate may be only modified to a slightly greater extent by the bones than by the soft tissue, and we get a characteristic plate, lacking in contrast, which is generally described by the term "flat." In an extreme case, nearly all of the radiation might pass through the body with only a trifling amount of absorption, and there would be no differentiation with reference to density and thickness upon the plate. Consequently, while no complete guide can be given, the general effect of increased spark gap is to reduce the contrast, and the general effect of increased exposure with moderate gap is to obliterate the details in the soft tissue or thin portions with an increase in the visibility of the shadows cast by the denser or thicker portions. If, for example, one desires a study of the thoracic vertebræ, one must expect that portions of the plate receiving radiation through the air-filled lungs will be greatly overexposed and will indicate no shadows. With a softer tube, details of the spine and ribs will be less obvious, while the linear markings in the chest are rendered visible. It naturally follows that tube condition and exposure should be adapted to bring out the information desired. Mention may also be made of the fact that the overexposed and denser regions may frequently give valuable information if viewed with a sufficiently strong source of light, while a thin negative, or those portions in which the shadows are faint and the total blackening slight, are best observed in weak light.

Inference as to pathology can only be safely made when due account is taken of the variation in the shadows due to normal variation in human anatomy and the procedure followed in making the negative.

Form 551
MEDICAL DEPARTMENT, U. S. ARMY
(Revised July 19, 1917)

CLINICAL RECORD
RADIOGRAPHIC REPORT

Station..
Date.., 191
From..
To..
....
Information requested:...
....
....
Clinical diagnosis:...
....
....
....
...., *U. S. Army.*

Laboratory...
...., 191
X-ray findings:

PLATE

NUMBER	SIZE	PART	DISPOSITION

....
...., *U. S. Army.*

SURNAME OF PATIENT CHRISTIAN NAME
....

RANK	COMPANY	REGIMENT OR STAFF CORPS

FIG. 58. Record and report form for x-ray examination (actual size 3½ ins. x 8 ins.).

Records.—The importance of the correct *recording* of all information obtained by means of the x-ray cannot be overestimated. Of equal or greater importance is the establishment of the identity of the patient examined with the x-ray findings. Furthermore, the identity of the *side* examined should be verified in every case.

That the x-ray findings are brought to the attention of the attending surgeon is essential. An actual conference between the surgeon and the roentgenologist is very desirable in order that each may have the advantage of the other's personal opinion.

Each plate should, therefore, be marked for identification by means of opaque markers and the corresponding information immediately recorded on the blanks provided for this purpose.

Form 551 Medical Department, U. S. Army (Revised July 19, 1917), will be used for this purpose, Fig. 58. In all cases a duplicate of this report should be retained.

LABORATORY EXPERIMENTS

Laboratory Instruction in Preparation for Roentgenology.—The following experiments are part of a series used in the laboratory course. They were easier of execution in the laboratory in which they were devised, and results were more conclusive, on account of having a very good high tension voltmeter so that tube voltage measurements could be accurately and quickly made.

The objects of such experiments are:

1. To give practice in quickly adjusting machine and tubes to any desired current and voltage.
2. To impress on the mind of the student the relation of the fundamental factors—voltage, current, distance and time—to the nature of image desired.
3. To assure the operator that results are reproducible if conditions are right.
4. To show some of the pitfalls usually encountered and to avoid having to acquire experience on the living patient.

While at first such experiments may seem very time-consuming, experience has shown that the skill and confidence acquired will much more than repay it in a comparatively short time.

New students, and even those of some experience, are likely to have trouble in handling the apparatus if it has many unusual details. They should, therefore, read such paragraphs of the manual as deal with the elementary principles, before starting experimental work.

The Coolidge tube is used in these experiments on account of its easy adjustment. Experience indicates that when taking the *same current* at the *same voltage* all tubes give very much the same density of negatives, so that exposures learned on the Coolidge tube apply to the gas tube in so far as the conditions can be made the same.

Experience in the training of a considerable number of students has clearly shown that the handling of x-ray apparatus *cannot be learned by seeing some one else do it.* Only when the students have repeatedly carried on the actual manipulations themselves, time after time, can they be depended upon under working pressure. Much time is lost in not knowing just what exposures should be given and the test plates described are excellent checks on accuracy and rapidity. The student should be well drilled in quickly setting the tube and control for definite readings. In the study of plates as well as in the technical work the student should do *absolutely individual and independent work.*

Instruction Unit.—A small instruction unit has been devised to clearly set forth the basic principles of the large x-ray machines and to avoid unnecessarily tieing up expensive equipment for elementary instruction purposes. This machine is composed of only the customary elements and these are arranged on an ordinary pine table so that all parts and all wires are completely in view and readily accessible. For instruction purposes high power is unnecessary, and a small transformer is ample for the purpose. With the transformer used, loads up to 5-inch gap, 30 ma., may be safely drawn for test plate and other experimental work. The autotransformer, rheostat, filament transformer, timer, etc., are standard parts as used on the large machines, so that the student may become familiar with their function and operation.

It is intended to have the machine as simple as it is possible to make it, and to this end the various circuits are distinguished from each other by the color of wire used. Thus, the main primary circuit is black, the motor circuit is blue, the Coolidge filament primary is red, and the remote control circuit is green. Even to a beginning student the circuits stand out separate and distinct, and the machine appears organized and rational rather than

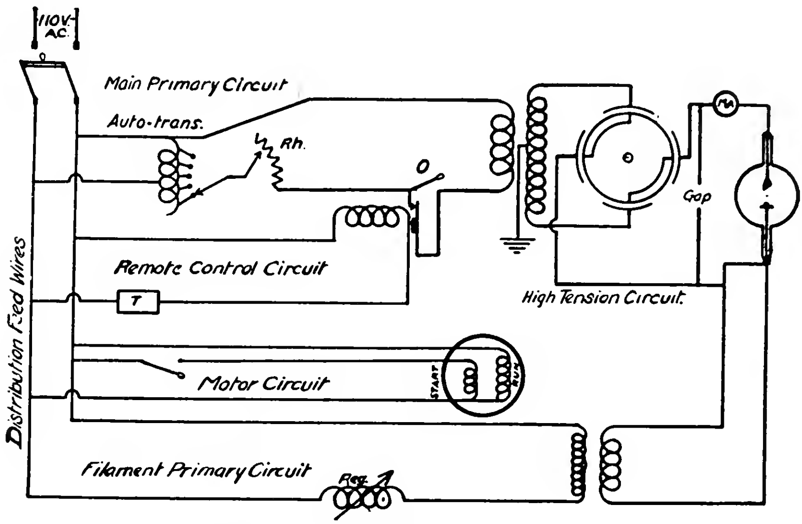

FIG. 59. Diagram of connections of instruction unit.

a hopeless maze of wiring. Fig. 59 shows the diagram of connections and Fig. 60 shows the machine itself. Superfluous parts have been eliminated and the features shown are so fundamental that each student should be able to wire up the complete machine as part of his laboratory work.

Aside from giving a knowledge of the electrical elements of x-ray machines, the unit is used to give considerable practice in setting for any desired tube voltage and milliamperage, in operating when failure of some non-essential

element occurs, and in studying the physical properties of the x-rays.

Test Plates.—The quantitative measurement of x-ray radiation has proved a difficult matter, but for our pur-

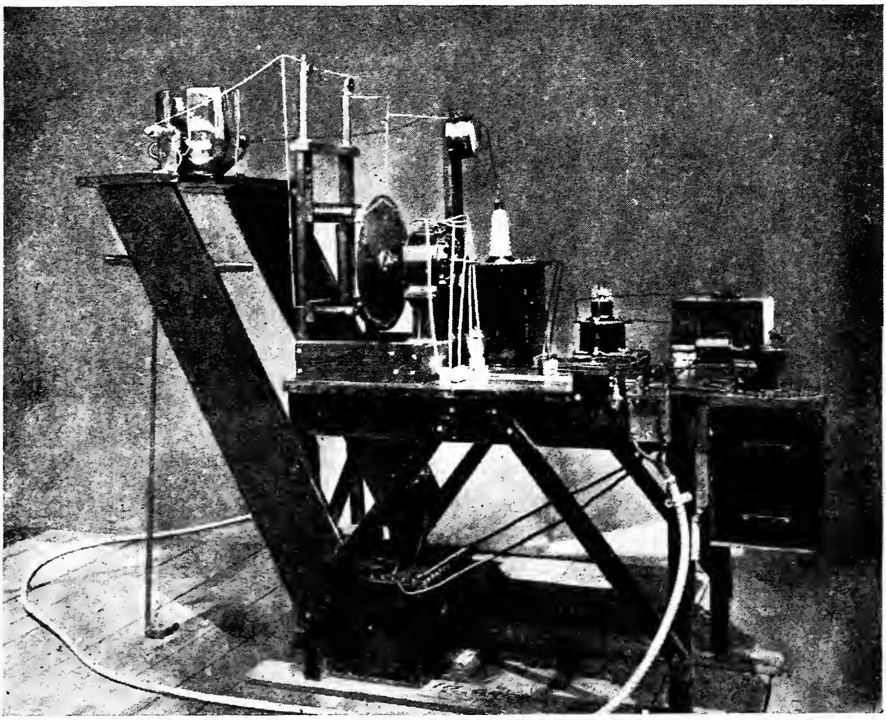

FIG. 60. Machine used for instruction purposes. All parts and wiring are openly displayed.

pose the photographic effect is sufficiently accurate and determines the usefulness of the rays in practice.

We cannot readily compare the radiation received on two spots of unequal density. Under any conditions of operation, however, if two portions of a photographic plate subjected to radiation and given the same develop-

ment have equivalent blackening we may say that the two parts *received the same quantity of photographically effective radiation* per unit area, or that they *had the same exposure,* in which case exposure does not mean time alone.

If a spot exposed 1 second and a spot exposed 2 seconds are of equal darkness, then we can say that the first spot was subjected to radiation twice as intense as the second, for it took only half as long to give equal effect. The spots should not be heavily overexposed or over-developed, for it is in the medium gray tones that distinctions in density are most accurately and easily made.

A 5 x 7 plate is cased in the usual envelope or in a light-tight plate holder. The student's name, laboratory number and the number of the experiment should be written on the emulsion side of the plate with soft lead pencil when loading. A 5 x 7 lead plate with ten 1-inch holes is used to protect the body of the plate from radiation and all holes except the one spot to be exposed are covered with sheet lead. Expose the test spots in proper sequence down the two rows of holes, and place a small metallic marker on spot No. 1 during exposure to identify it later.

In using a timer do not vary its settings, as the scales are rarely calibrated with sufficient accuracy. Keep the timer set at 0.1 second and repeat the exposure the required number of times. If the machine is not equipped with a timer capable of conveniently repeating 1/10 second exposures, time with a stop watch or by counting to full seconds instead of tenths. Increase considerably the target-plate distance in this case, if possible.

Do not develop test plates too far. Stop as soon as

spots Nos. 1 to 5 show fairly well on the back of the plate. If the settings have been carefully made and exposures accurately timed, spots Nos. 1 to 5 should be approximately equal in density and Nos. 6 to 10 should run successively darker or lighter as the case may be.

When the finished plates are dry the spots should be numbered and all exposure data written on the emulsion side of the plate with pen and ink. The plate should then be turned in for inspection and credit.

Before commencing work read and understand the general instructions and precautions on page 20.

Distance-Time Relation—Inverse Square Law.

Test Plate 1.—The x-rays travel out from the electron impact point on the target in straight lines, so that the amount in a cone of a given angle is spread over an increasing base area as we recede from the tube. A plate of fixed size intercepts more radiation in a given time when close to the source. If we move a plate to double its original distance from the target, the radiation received per second on a given area will be only ¼ as great; at ten times the distance, 1/100 as great. In order to secure the same radiation effect, the time of reception must be increased four-fold in the first case and one hundred fold in the latter.

For *constant tube current and voltage* the plate blackening will be unchanged if we keep $\frac{\text{time}}{\text{distance}^2}$ constant for all exposures.

Set for 10 ma. at a 3-inch spark gap and expose spots as shown below. Or the bedside unit may be used, exposing seconds instead of tenths.

Spot No.	Distance	Time	Spot No.	Distance	Time
1	10 in.	.1 sec.	6	10 in.	.1 sec.
2	20 "	.4 "	7	20 "	.1 "
3	30 "	.9 "	8	30 "	.1 "
4	40 "	1.6 "	9	40 "	.1 "
5	50 "	2.5 "	10	50 "	.1 "

In the first row of spots we have compensated for the change in distance by a proper corresponding change in time, so these spots will have the same density. In the second row we have made no such compensation and the spots will not be equally dark. The target-plate distances ordinarily used in radiographic work vary from 15 to 36 inches. The sharpness of the radiograph increases with greater distance, but longer time is required. Assuming that 1 second is the correct exposure for a given object at 20 inches, plot a curve on cross section paper showing time required at various distances up to 36 inches to give the same density of plate.

Current-Time Relation.

Test Plate 2.—The x-ray energy on a given plate area per unit time when the voltage is constant and the target-plate distance is fixed, increases in direct proportion to the current. Thus, we get the same radiation in *half* the time when using 50 ma. as when using 25 ma. Or, for equal photographic effect the product of milliamperes and seconds must remain constant.

To test this law expose a test plate as follows:

Voltage constant at a 4-inch gap.

Target-plate distance constant at 30 inches.

Spot	Current	Time	Spot	Current	Time
1	5 ma.	1.2 sec.	6	5 ma.	1.2 sec.
2	10 "	.6 "	7	10 "	1.2 "
3	15 "	.4 "	8	15 "	1.2 "
4	20 "	.3 "	9	20 "	1.2 "
5	30 "	.2 "	10	30 "	1.2 "

Notice that we have compensated by a decrease in time for the increase in current in the first row and that the second row is uncompensated.

Voltage-Time Relation.

Test Plate 3.—The radiation leaving a given target as registered by a photographic plate is not fixed by the amount of current alone, but varies greatly with the drop in voltage through the tube. In fact, it increases very nearly in proportion to the *square* of the voltage. This means that on doubling the voltage, all other factors remaining unchanged, we get four times the photographically effective radiation per second and would then need but *one-fourth* the exposure time.

With an electrostatic high tension voltmeter it is easy to read voltage directly, but this instrument is not ordinarily available. The so-called primary "kilovoltmeters" with which many machines are equipped are not reliable indicators of secondary voltage, as they do not read the same for the same secondary voltage under different loads on the transformer. Parallel sparking distance between blunt points is our best available guide to tube voltage. The relation between spark length and kilovolts is shown in Fig. 12. It may be considered as reasonably true that

under average conditions the kilovoltage is ten times the spark in inches plus ten, i. e., 3-inch gap = 40 kv.; 5½-inch gap = 65 kv., etc.

Exposures are to be made as follows:

Current constant at 5 ma.

Distance constant at 25 inches.

Spot	Gap	Time	Spot	Gap	Time
1	2″ (30 kv.)	1.6 sec.	6	2″ (30 kv.)	1.6 sec.
2	3″ (40 ")	.9 "	7	3″ (40 ")	1.6 "
3	4″ (50 ")	.6* "	8	4″ (50 ")	1.6 "
4	5″ (60 ")	.4 "	9	5″ (60 ")	1.6 "
5	6″ (70 ")	.3* "	10	6″ (70 ")	1.6 "

* These figures are fair approximations to the exact values.

The equality of density of numbers 1 to 5 as well as the great density difference of numbers 6 to 10 illustrate well the effect of increased voltage.

It must not be assumed that the quantity of radiation alone varies with the voltage at constant current and time. The ability to pass through material also increases to a great extent at higher voltage. The quality of negatives of the same average density made at high and at low voltage is quite different and a voltage (penetration) suitable for the case in hand should be chosen if the best results are to be secured.

Summary of the Preceding Relations

Test Plate 4.—Formulating the experience derived from the preceding experiments, we may conclude that for a given tube and machine—i. e., a fixed wave form, frequency, target, and absorbing glass wall—we may regulate

the exposure, when no absorbing material is traversed, by control of (a) current, (b) voltage, (c) time, (d) distance.

Expressed in algebraic form, the photographic effect E is given by

$$E = \frac{K \text{ x Current x (Voltage)}^2 \text{ x Time}}{(\text{Distance})^2}$$

where K may change for various targets, glass walls, or wave form, but is fixed for a given tube and outfit. If this is true, one can readily compute from *one* set of conditions the length of time under other conditions that will give the same plate density.

To calculate the time for a given exposure use simple approximate methods, not long and involved computations. Thus, if a case is given as follows:

Exposure 1:

50 ma.—5-inch gap—18 inches—4 seconds.

Exposure 2:

15 ma.—4-inch gap—27 inches—time = ?

Decrease in current increases time 10/3 times.
Increase in distance increases time 9/4 times.
Decrease in gap increases time 25/16 = 3/2
Then the required time is

$$\cancel{4} \text{ x } \frac{\overset{5}{\cancel{10}}}{\cancel{3}} \text{ x } \frac{9}{\cancel{4}} \text{ x } \frac{\cancel{3}}{\cancel{2}} = 45 \text{ seconds.}$$

Start with 4-inch gap 10 ma. 20-inch target-plate distance, and .2 sec. Calculate and expose 11 spots so as to vary two or three of the above factors each time, but keep E constant. $E = \dfrac{(4)^2 \text{ x } 10 \text{ x } .2}{(20)^2} = .08$ arbitrary units for spot

No. 1. Thus, if current is raised to 30 ma., this increase would give a time $1/3$ as great; but if the distance is raised to 30 inches the greater distance would require a time $9/4$ as great. Hence the correct time with the combined change is $.2 \times 1/3 \times 9/4 = .15$.

Do not work below a 2-inch gap on account of the absorption of the glass walls of the tube, or on the small instruction units above 5 ma. on a 6-inch gap or above 30 ma. on a smaller gap.

Use a variety of control buttons, and where the timer will not give exact results, get as near as possible or vary one or more factors to get exact tenths. The timer will not give smaller fractions with any considerable accuracy.

The exposures are to be computed before coming to the laboratory.

Enter your results as follows:

No.	MA.	Gap.	Distance	Time
1	10	4″	20″	.2 sec.
2	5	5″	25″	?
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

If correctly done, no variation in darkening will be observed.

Change in Time of Exposure with Thickness

Test Plate 5.—Exposure Factor. Find by trial the ratio of the time required to get the same density through *one* layer of a paraffin as when no absorber is present. To do this, expose a plate, using a machine setting of 10 ma., 3-inch gap; or use the bedside unit, exposing seconds instead of tenths and giving the plate much shorter development. Use 17-inch distance for all spots.

Spot No.	Layers of Paraffin	Time	Spot. No.	Layers of Paraffin	Time
1	0	.1	6	1	.4
2	0	.2	7	1	.5
3	0	.3	8	1	.6
4	1	.2	9	1	.7
5	1	.3	10	1	.8

When the plate is developed compare other spots with Nos. 1, 2 and 3, and select the pair that comes closest to an exact match in density. If, for example, spots No. 1 and 5 are equally dark, the exposure factor is determined by the ratio of the time of exposure used—in this instance, 3.

This factor can be checked by comparing spots No. 2 and 8, which should match if the factor is 3.

A method similar to this can be used to obtain the speed ratio of intensifying screens, exposing part of a plate with a screen and part without, as suggested elsewhere in the manual, Fig. 52, page 114.

Absorption of rays and scattering gives an explanation of the great increase in time of exposure with increasing

thickness of absorbing layer. Thus, if experiment shows that a certain thickness of a given material will reduce the emerging radiation to 3/5 the incident, then a spot exposed through this layer will require 5/3 the time for the same photographic density as the uncovered portion of the plate would require. For two such layers 25/9 the original time will be required, for three layers 125/27, etc.

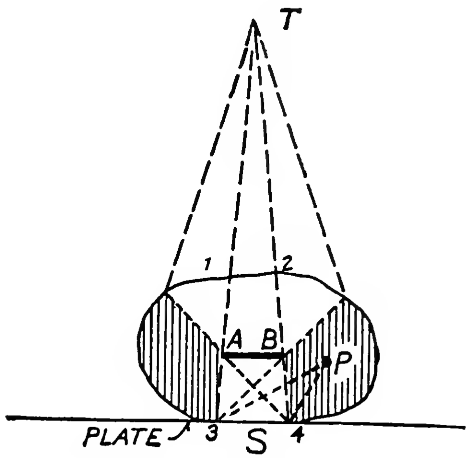

FIG. 61. Effect of scattering on undercutting of image.

(*Test Plate 6*). Using the factor obtained from Test Plate 5 and the law indicated above, calculate proper exposure times and expose the plate as follows:

Machine setting constant at 10 ma., 3-inch gap, 30-inch distance; or use the bedside unit, if it was used for Test Plate 5, again exposing seconds instead of tenths and giving the plate short development.

Spot No.	Layer of Paraffin	Time	Spot No.	Layer of Paraffin	Time
1	0	.3	6	0	.3
2	1	..	7	1	.3
3	2	..	8	2	.3
4	3	..	9	3	.3
5	4	..	10	4	.3

The time for proper exposure in order to get the best plate does not work out from the simple law of absorption. The reason is clear when we consider scattering in tissue. Let *AB,* in Fig. 61, be a small object in the body, relatively opaque to x-rays. If there were no scattering, the area *S* would be protected from radiation by an amount fixed by the *increase* in absorption of *AB* over that of an equal amount of tissue. Thus, if volume represented by 1, 2, 3, 4 would absorb 95 per cent when *AB* is absent, then if the object were *entirely* opaque it could only reduce exposure by 5 per cent of that adjacent to it. In addition, all the shaded portions of the figure are sending scattered radiation to *S* in proportion to what each point receives. To reduce this scattering as much as possible no more of the body should be exposed than is necessary, and conditions maintained to give as high contrast as possible. The best plates of thick parts are rarely of high density as compared with those of extremities. Contrast is always better when the gap is made as low as possible, consistent with other operating conditions.

The Benoist Penetrometer

Test Plate 7.—X-rays are caused by the violent change in the speed of electrons, and the quantity and quality of the beam will depend on the number of electrons involved, their speed, and the suddenness of their stop. By quality, we should specify the relative intensity of each wave length. As the operating voltage is increased, there is a great increase in the electron velocity. Thus $Ev = \frac{1}{2} MV^2$, where E is the electronic charge, v the voltage, M the mass of the electron, and V its speed.

There is no way of easily analyzing a beam and so the ability of the shorter waves to pass through material is used to give a rough idea of the quality. This penetration is only approximately indicated by a penetrometer. The Benoist penetrometer may be used to test out exposures and to secure a more accurate knowledge of the factors governing plate density than can be easily acquired otherwise.

Use a lead cover having twelve holes to take a fairly large penetrometer. Use sheet lead to cover parts of plates not being exposed. Remove the holder from the table and cover all portions while adjustments are made, in order to avoid fogging. Take considerable care in adjusting the tube, and note carefully the exposures specified. Study your plate and see how it checks out with the computed times for equality of density as far as the blackening under the silver is concerned.

Silver is approximately a non-selective absorber for the range of wave lengths used in practice, while the aluminum absorbs "soft" rays in excess. Read the "hardness" by noting the number of the aluminum sector that gives the same photographic density as the silver. That sector giving the highest plate density is called No. 1, and the others number consecutively. Discuss carefully the difference seen in the negative. Make the following exposures with fairly careful settings.

Target-plate distance, 15 inches.

Row 1			Row 2			Row 3		
Ma.	Gap	Time	Ma.	Gap	Time	Ma.	Gap	Time
10	2″	1.2	10	2″	1.2	10	2″	1.2
15	2″	.8	10	3″	.7	15	3″	.4
20	2″	.6	10	4″	.4	20	4″	.2
25	2″	.5	10	5″	.3	25	5″	.1

Tabulate the Benoist hardness and voltmeter readings, also plot on cross section paper. What relation exists in the incident radiation among the above exposures?

The *longer* wave lengths are absorbed in excess, and the remainder of the beam as transmitted contains an excess of short waves. Such a beam is said to be filtered.

Note.—The Benoist penetrometer is not a very useful or reliable guide as to tube quality—not nearly so satisfactory in transformer operation as spark gap; but it does serve to give an idea of penetration difference if one is sure that the same *quantity* falls on the instrument in each case.

NEW APPARATUS

In the following pages of this manual there will be described some new apparatus and appliances which have been developed with advice of many roentgenologists and surgeons with the sole intent of aiding the service. This apparatus was not designed to secure novelty, or simply to be different from other devices, but with a view of securing, first, simplicity and convenience, second, elimination of error and unnecessary steps and, third, to secure manufacture at such a rate as will enable the product to be used at the earliest possible moment.

It is urgently desired that every roentgenologist to whom this apparatus is delivered take the time necessary to study it over and to acquire, at least initially, the point of view of the designer. Simply because some particular feature with which he has been familiar, and which has been more or less fashionable among roentgenologists, is missing, is not a sufficient excuse for general condemnation or rejection of the standard outfit. After making sure that the apparatus is properly assembled every operator should go rapidly through the steps in handling it with a view to smoother operation and to saving time. The instructions which are given may serve as a basis for such self-drill, and it is of course to be expected that many modifications of procedure and inexpensive additions to equipment may readily be provided on the initiative of the operating roentgenologist.

Every roentgenologist is advised to file and retain all copies of instructions and catalogues or blue prints fur-

nished with the outfit by the manufacturer. These may be of considerable assistance in case of breakdown or damage, even though the directions, in some measure, do not correspond with the general instructions given in this manual.

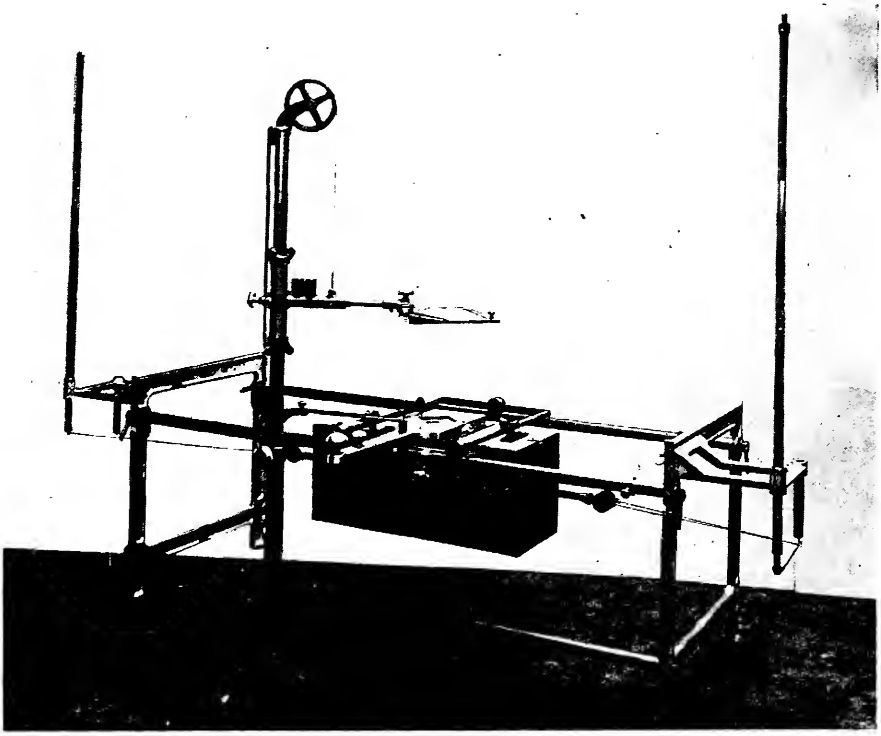

FIG. 62. Standard U. S. Army x-ray table with insulating masts and holders and box for standard type tube.

Army X-Ray Table.—The standard x-ray table consists of the following principal parts: (Figs. 62 and 63.)

1. Two aluminum end castings.
2. Three steel side rails.
3. A rectangular frame as a tube-box cradle.
4. A lead-covered tube box.
5. A special detachable shutter.

6. A rectangular wooden frame supporting a stretcher type top.
7. An operating switch.
8. A special screen carrier.
9. High tension vertical insulators.
10. A tube holder for working above the table.

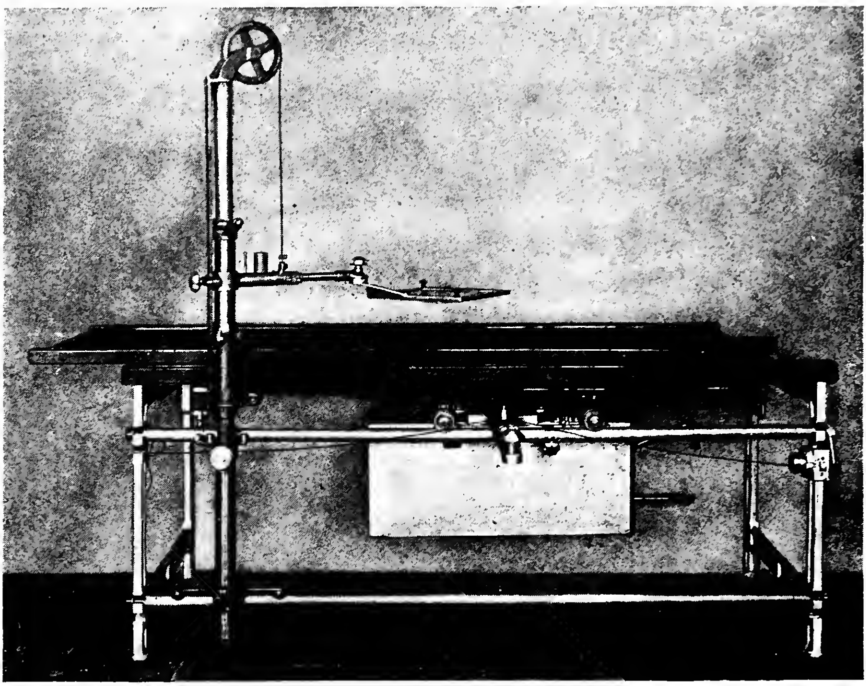

FIG. 63. Standard U. S. Army x-ray table complete with box for radiator type tube.

When the table is to be used with the portable outfit a tube box designed for the radiator type of tube must be used. For the usual base hospital outfit, a tube box taking the standard tubes is supplied. In the former the high tension insulators both enter the same end of the box, in the latter they enter at opposite ends. Any or all of numbers 8, 9, and 10 may be omitted in special cases.

In the description following, numbers in parenthesis refer to the figures in the text, *not* to manufacturers' stock or replacement numbers.

End Castings.—(Fig. 64) The end castings (41) have four slots (42) on each side. These take the ends of the steel side rails. *Two* rails (45) are used on the operator's side of the table and *one* on the other side. When using the regular top the rails should be placed in the

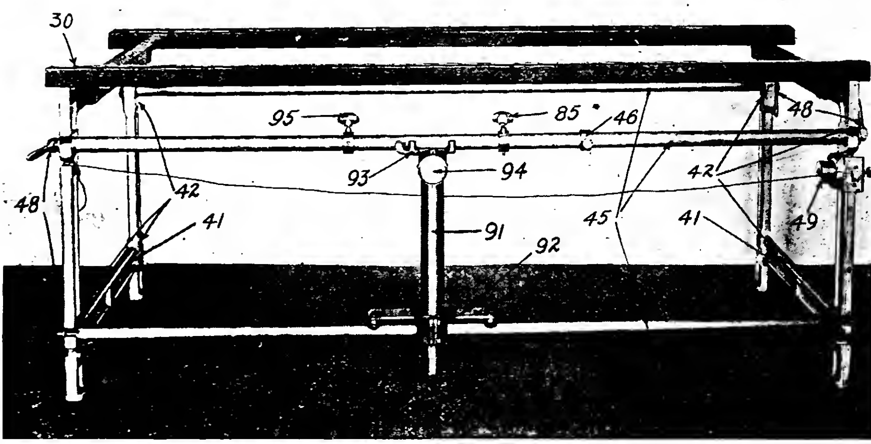

FIG. 64. Framework of standard army x-ray table and operating pull switch (49).

upper of each pair of slots. If one must use an army litter, use the lower slots. Holes are provided to mount the masts for overhead work.

Rails.—(Fig. 64) The round rails have tightening screws (48) with permanently attached handles. Sliding on one of these rails are three rings (46, 85, 95). The one at the left serves to lock the screen carriage, the center one locks the tube box against longitudinal run and also may be used to secure a tube shift of either 10 or 15 centimeters. The right-hand ring serves in measuring any desired tube

shift. These should always be placed on the rail in the order shown.

Cradle.—(Fig. 65) The cradle has three roller-bearing wheels (81) to give longitudinal run on the side rails. The single roller on the right has a screw brake to be used when lifting the box. The cross piece on the

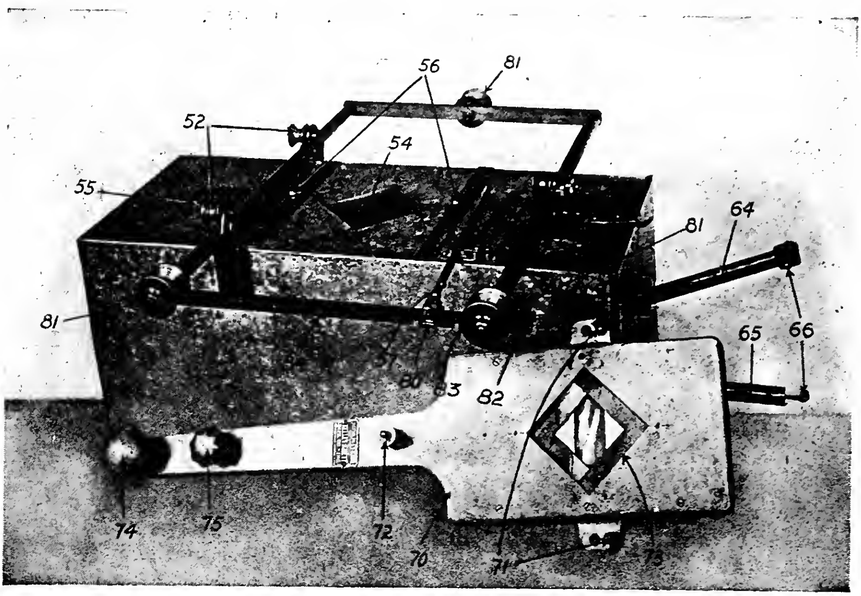

FIG. 65. Details of tube box, cradle and shutter, standard army x-ray table.

operator's side carries a tube box brake (57) for lateral locking when in use, also three stops for tube shift measurement. The one near the center (84) is permanently attached, as is also the one at the right (82). The third (83) is placed close to the roller and when the ring (85) is placed between (83) and (84) we have a 15 cm. shift; by changing the position of the screw (57) of the cross run brake, we may secure a 10 cm. shift between stop (84) and the stop (80) on the brake.

Box.—(Figs. 65, 66 and 67) Two types of box are built, one for use with the radiator type Coolidge tube, the other for the ordinary tubes. *The former must be used on all portable outfits,* the latter is known as the base hospital tube box. In the *portable box both insulators enter at one end.* In the base hospital one is placed at each end.

In both boxes the tube mount slides into the box at the

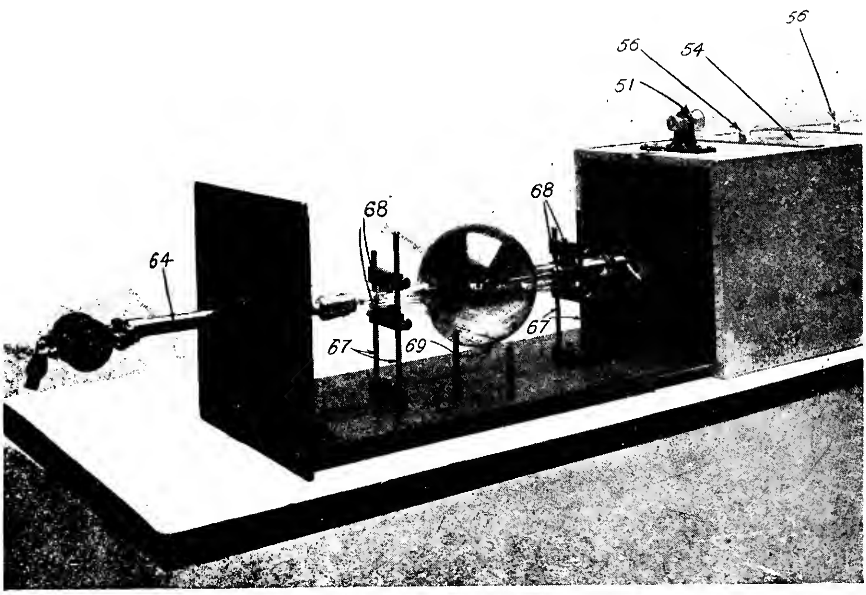

FIG. 66. Mounting of standard type tube in army x-ray table.

end. Fig. 67 shows the mounting with insulators for the radiator type of tube. The partition (62-63) is covered with lead rubber and the upper portion is removable for insertion of the tube. The tube may be raised or lowered or shifted longitudinally for centering. The insulating posts with the transverse wire (69) are used in adjusting the target position. All connections to the tube are to be made *before* inserting the slide in the box.

Shutter.—(Fig. 65) The shutter has double slides;

one pair controlled by the outer knob (74) gives a diamond-shaped opening; that controlled by the inner knob (75) gives a slit parallel to the length of the table. The shutter is attached to the box by the pins (56) and clamps (71), as shown, and these must be closed before using.

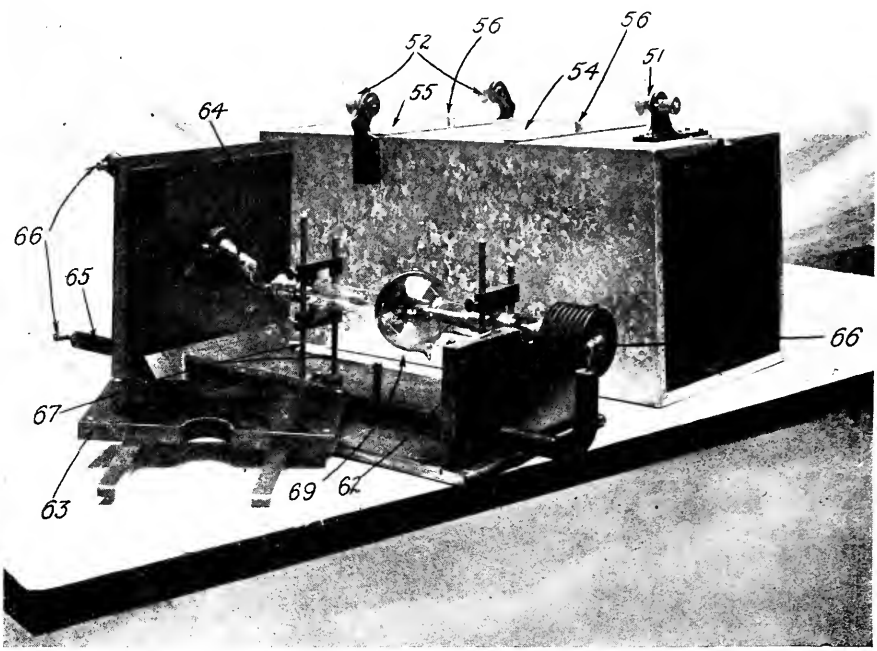

FIG. 67. Tube box and mount for radiator type tube, standard army x-ray table.

Top.—(Fig. 64) The rectangular frame (30) is narrower than the supporting ends of the table, permitting a slight lateral shift of the patient without disturbing him on the stretcher. A raised ridge projects on one side to engage a groove in the stretcher type of top. This allows a certain amount of longitudinal shift. A little paraffin as a lubricant on the ridge will serve to make the top move readily, even with a heavy patient.

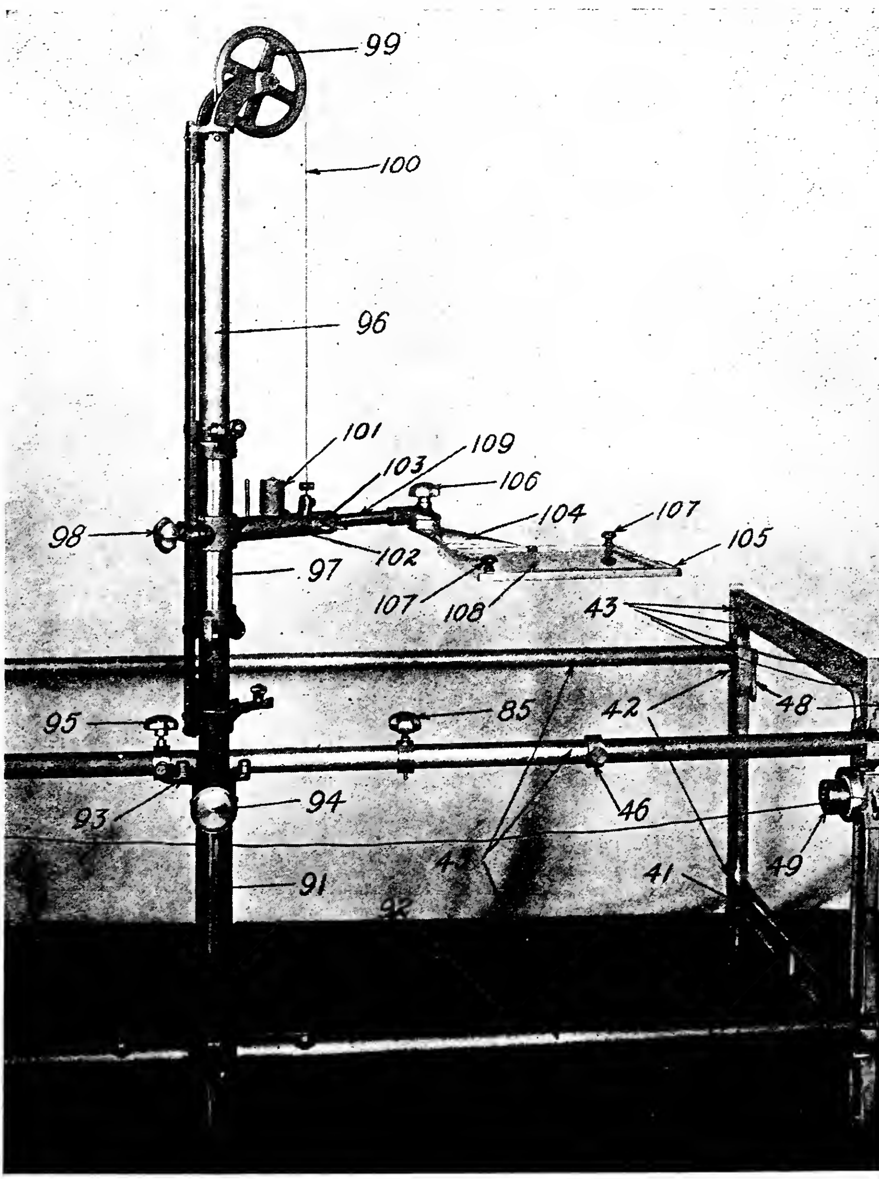

FIG. 68. Screen-carrying mechanism, complete standard army x-ray table.

Switch.—(Fig. 64) When using the "Delco" engine to operate the portable outfit the switch may open and close *two* circuits; in this case the *usual foot switch cannot be used.* A special pull switch (49) operated by a string running along the rail is supplied.

Screen Support.—(Fig. 68) The screen support was designed to enable the screen to be carried to any working position parallel to the table top without having any portion obstructing the work of the operator. For localization work it may be locked in any desired position.

It has the following features:

1. It runs freely on the two side rails.
2. It is counterbalanced so as to run up and down with ease.
3. It may be rotated about two vertical axes, enabling the pierced center of the screen to be brought easily into position.
4. It may be locked against each motion separately.
5. It may be locked as to up and down motion and yet rotate.
6. The screen may be inclined if need arises. The carrier is mounted in a tube (91) with bearings running on the lower rail, and three rollers (93) on a vertical axis hold it in line on the upper rail. (96) is a heavy tube fitting into (91) and turns on a cone bearing at the base. (109) is an adjustable rod to which is attached the screen clamp (106). (98) is the clamp for vertical motion; (95) for longitudinal run; (94) for rotation in the tube; (106) for rotation about the corner of the screen.

Vertical Insulators.—(Fig. 62) The special insulating masts may be used as follows:

1. In base hospital work with an overhead wiring system they serve to connect to the tube box. They are

then placed, one at *each end* on the *operator's side* of the table.

2. To connect the portable instrument box for work with tube above the table. They are then placed both at one end of the table. Two extra reels and a tube holder are needed for this arrangement.

Setting Up Table (Portable)—

1. Unpack all of outfit and check list to ensure that no parts are mislaid.
2. Decide on position for table and instrument box, and which shall be the operating side of table.
3. Lay two rods (45) down on side to be used by the x-ray operator; one of these must have locking and stop rings.
4. Place end frames (41) in position and drop rods into notches. Use all upper notches unless army litter is to be used.
5. Place screen roller carriage (91) in position and tighten end screws on all rods. Run (91) to left of operator's position.
6. Hook cradle under rollers on tube box with the two roller ends of cradle on the operator's side of the table. *Lock cross brake* (51) and set cradle on rails, then release brake (51). Attach working cross lock and be sure it is in proper position. See Fig. 65.
7. Attach diaphragm (70) to box and lock in position.
8. Set (96) into (91), then attach screen and clamp with screw (103).
9. Unlock (98) and put on enough small weights to counterbalance the screen.
10. Attach pull switch to the end of table toward instrument box.
11. Pull out drawer from tube box and place on a good support.

12. Remove cover of inner box of tube shipping case by unhooking the hasps at each end, and raise the corner by grasping each hasp.
13. Place the tube in position shown in Fig. 67. Make the cathode connection by turning the tube in the holder before tightening. Then, approximately center and tighten holder. Connect to the radiator by means of a short piece of wire. Do not use screw as a binding post.
14. Place rectangular frame (30) with ridge away from operator.

NOTE.—Be sure to retain the box intact in which the tube is shipped, and in case of reshipment proceed as follows:

To pack the tube, place it in the inner box so that the radiator is ¼ inch from the end of the box.

Place cover of inner box in position.

Press cover down carefully and close spring hasps, being absolutely sure that the hasp is hooked.

After closing cover of outer box, fasten down by means of the hasp provided for that purpose.

Cautions—

1. Do not bend, bruise or jamb parts.
2. Do not remove screen without first locking (98), as counter weight may cause damage.
3. Do not turn screws so tight that threads are stripped.
4. Do not fail to set cross run brake (51) before lifting tube box off or on.
5. If the supporting side rails are slightly bent the tube carriage will run hard or bind. Place box in the middle of the run and, loosening the end nuts, (48) rotate upper rods about their own axes until the single back roller is free on both sides, i. e., does not rub on its support.

6. Always remove screen from its holder before removing screen carriage.
7. Note the cone bearing on the lower end of the carrier post. Do not stand the carrier on this, as it may easily be roughened.
8. If the screen carrier does not run freely or is too loose at the top, the eccentric mounting on the inside of the roller bearing should be loosened and adjusted so that there is very little play between these rollers and the rail. If tightened in this position the carrier will run freely.

Also, note that the ring (95) has a hole 90° from the handle into which a small thumb nut projects, making the attachment with the movable carrier; while (85) has a projection intended to engage a slot on the under side of the cross piece of the cradle, to serve as a lock for longitudinal run of tube box.

Some Operating Points.—After the table is set up and made reasonably level and all adjustments have been made, it is strongly advised that the operator practice manipulation until he can instinctively and certainly grasp the locking devices whenever necessary for his work.

There are, then, six knobs to be operated, three controlling the screen carrier and three the tube box and diaphragm.

Number 106 will usually be set according to the operator's idea of using the screen and need not generally be unlocked.

It is expected that the operator will stand between the screen carrier and the diaphragm control, using the right hand to control the screen box and its locks. It may be suggested that if the operator will acquire the habit of grasping the rod (109) in order to control the screen position, the left hand need never be in the radiation, and

the right hand can remain free to control shutters and rail lock, Fig. 69. A little time spent in adjusting one's

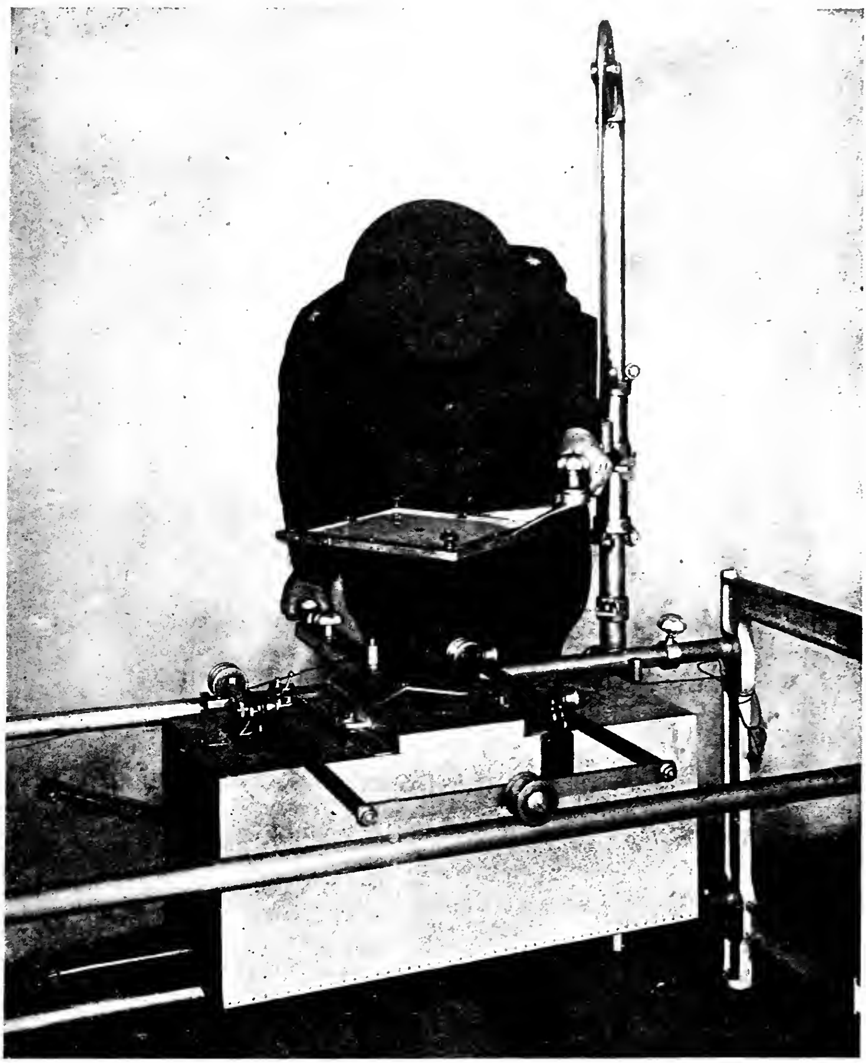

FIG. 69. Method of handling screen and shutter on all standard army x-ray tables. Litter top removed.

motions and ideas to those that prevailed when the apparatus was designed will greatly expedite its accurate use.

List of Numbers Referring to Illustrations of Standard Tables

Numbers refer to the illustrations and *not* to manufacturers' stock or replacement numbers.

PART.	NO.
Top	
Rectangular frame	30
Bakelite stretcher	31
Frame	
End frames	41
End frame slots	42
Holes for mast support	43
Rods (side rails)	45
Ring stop	46
Screw handles on rods	48
Switch	49
Tube Box	
Roller with cross run lock	51
Rollers without lock	52
Aluminum window	54
Ventilation opening	55
Register pins for shutter	56
Lock, cross run	57
Partition (lower half)	62
Partition (upper half)	63
Insulator (cathode)	64
Insulator (anode)	65
Binding Posts	66
Tube support posts	67
Tube clamp	68
Tube centering wire	69
Shutter	
Shutter complete	70
Shutter clamps	71
Screen carrier connecting post	72
Diaphragm opening	73
Diamond-opening control	74
Slit-opening control	75

PART.	NO.
Tube Box Cradle	
Stop position for 10 cm. shift	80
Rollers	81
Stop for variable shift	82
Stop for 15 cm. shift	83
Stop	84
Lock to rail	85
Screen Carrier	
Socket bearing	91
Lower rail carriage frame	92
Upper rail bearing rolls	93
Clamp against rotation	94
Clamp against longitudinal run	95
Main post	96
Sliding sleeve	97
Clamp (vertical position)	98
Pulley	99
Wire cord	100
Balance weights	101
Socket for horizontal arm	102
Clamps (screw)	103
Screen holder frame	104
Screen holder latch	105
Screen clamp	106
Knobs to lift screen	107
Screen	108
Rod to screen frame	109
Additional High Tension Insulators	
Vertical masts	21
Frame for supporting masts	22
Short insulator for keeping high tension wires away from frame	23

Fluoroscopic Room Illumination.—It is strongly urged that the lighting of fluoroscopic rooms be properly arranged. One should have a dim light for use in placing patients, etc., and no light when fluoroscoping. The portable outfit provides for operating the needed light from the Delco generator. When the operating switch is closed the lights go out, and on opening this switch they are automatically lighted. It is advised that a ruby lamp be used intended for operation on a circuit above 110 volts. The connection used with the portable unit is shown in Fig. 76 and a similar connection can be made for other outfits.

To Find Target-Screen Distance.—On the standard army x-ray tables the following method will serve to measure the distance from target to screen:

The upright support U fits in the tube Q, Fig. 70 and the screen carrier is fastened to the sliding sleeve R. The distance from the top of the tubing Q to the under side of R is related to the target-screen distance F_0S as shown, $F_0S = n + d + l$ where n and l are fixed lengths. Hence if *one* target-screen distance is found, $n + l$ can at once be determined.

Put the cross wire marker on the table in the vertical ray. Shift the tube by use of the table stops an exact distance, say 10 or 15 cm., and adjust the screen up or down until the image shift and tube shift are equal. Then the target-screen distance is twice the distance between screen and cross wire marker.

Measure the distance BX and subtract this from the length so found, and the difference is $l + n$. Record this on a shipping tag and attach to the table. Thereafter, if the target-screen distance is required, measure BX and add $l + n$ as recorded.

To check your measurement lay a strip of metal about four inches long on the table. Raise the screen until the

shadow becomes twice the length of the strip. Measure screen-object distance and double the result for *FS*.

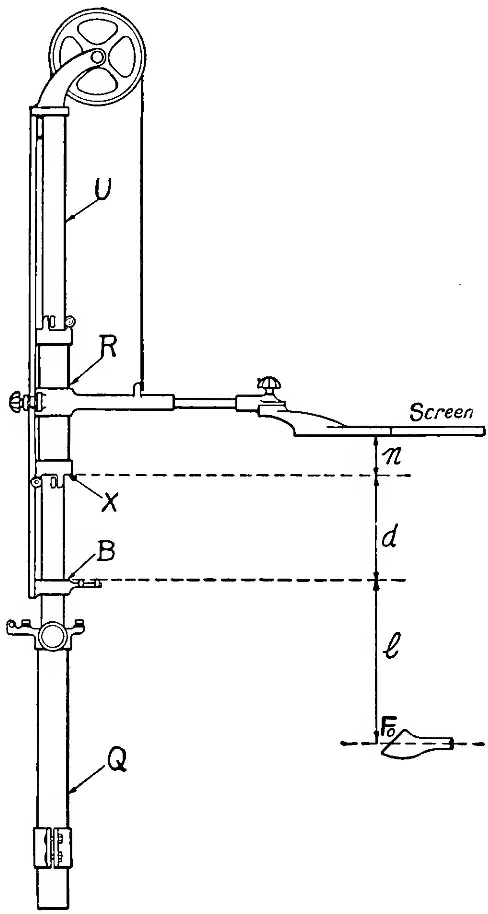

FIG. 70. Measurement of target-screen distance, standard screen carrier.

Examples—

1. Using a 10 cm. tube shift and setting the sliders of method A 10 cm. apart, a piece of lead was placed on the table and its edge so placed that its shadow coincided with one of the metal edges of the marker; shifting the tube 10 cm., the screen was raised until the shadow of the lead

coincided with the other marker. The object-screen distance was then 38.7 cm. The target-screen distance was then $38.7 \times 2 = 77.4$.

2. With length of shadow double that of the object, the actual distance between screen and the object was 39 cm. Double this, or 78 cm., equals the distance between the plane of the screen and the plane of the focal spot of the target.

78 cm.	=	total distance screen to target
45 cm.	=	variable distance
33 cm.	=	the distance that the sliding or adjustable piece on the upright arm of the wall meter is to be raised and set above the brass lug on the lower right.

Centering Tube in the Box Beneath the Table.—It is desirable that the focal spot of the target should be vertically below the center of the diaphragm in the various methods of localization. In order to determine whether this is the case, proceed as follows:

1. Close up the diamond-shaped opening of the shutter to about ½ inch.

2. Lock the tube box in position and bring the opening of the screen so that the illumination shows symmetrically thereon.

3. Suspend a small metal ball, *B*, by a string passing through the center of the opening, and observe when this ball comes to rest whether its shadow falls symmetrically upon the projection of the diaphragm. If not, or if on narrowing the diaphragm still further, the narrow beam of rays passes by the ball so that it does not cast a shadow on the small illuminated area of the screen, it is evident

that the tube is not properly centered, and the position of the shadow also gives an indication of the direction of tube movement require. Fig. 71.

An approximate idea of whether the tube is properly centered or not may be gained by bringing the perforation in the center of the screen to the center of the projection of the small diagonal opening of the shutter. When the

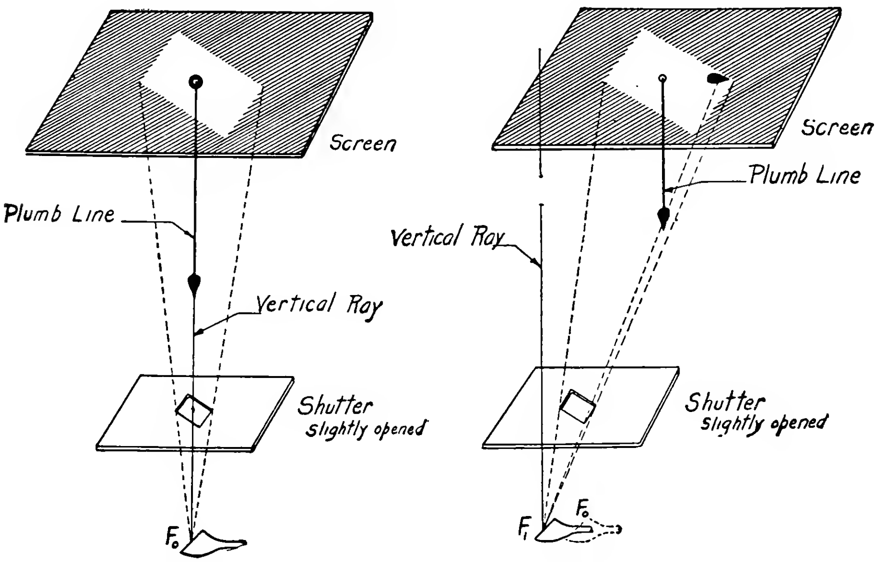

FIG. 71. (a) Correct position of shadow of plumb bob. Tube properly centered.

(b) Projection of plumb bob on fluorescent screen, incorrect position.

screen is down close to the table with the carrier locked against longitudinal motion and against rotation, raise the screen by the vertical movement of the carrier and see whether it retains its symmetrical position. An idea of the amount by which the tube needs to be shifted may be obtained in this way.

It is also suggested that, if the tube needs to be moved in the direction in which the holder slides out of the box, one can slide the holder itself out and test for correctness,

measure the distance, and finally shift the tube the same amount.

The U. S. Army Portable X-Ray Unit.—By the coöperation of various manufacturers a semi-portable outfit has been developed which may be used in mobile units. The unit is shown in Fig. 72 and diagramatically in Fig. 73.

The important features of the outfit are the portable power plant, the self-rectifying Coolidge tube, and the

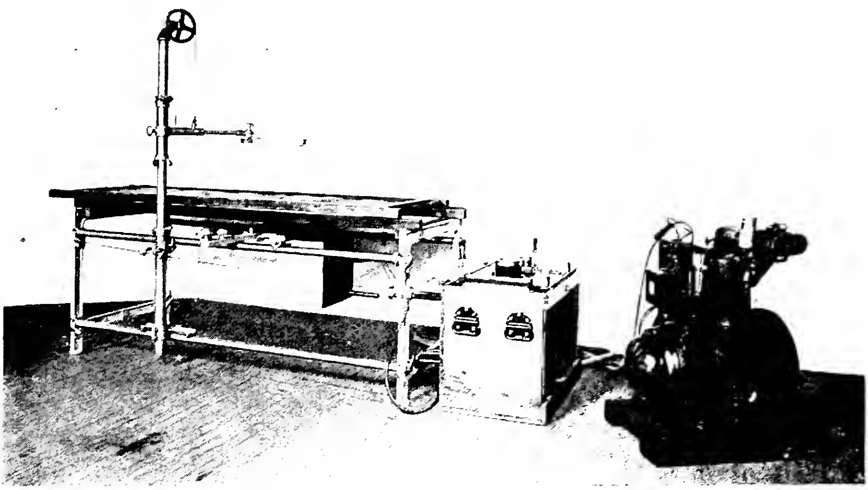

Fig. 72. United States Army portable x-ray unit complete.

special table. Having the complete generating equipment, it is admirably adapted to service in strange territory where the electrical supply is not suitable for standard machines or is likely to fail because of war conditions.

The gasoline engine is direct-connected to a generator which supplies power for the x-ray and filament transformers (a.c.) and a small amount of current (d.c.) for the control circuit. The primary circuit requires no control resistance, regulation for the two working settings being made by shifting the throttle by means of the d.-c.

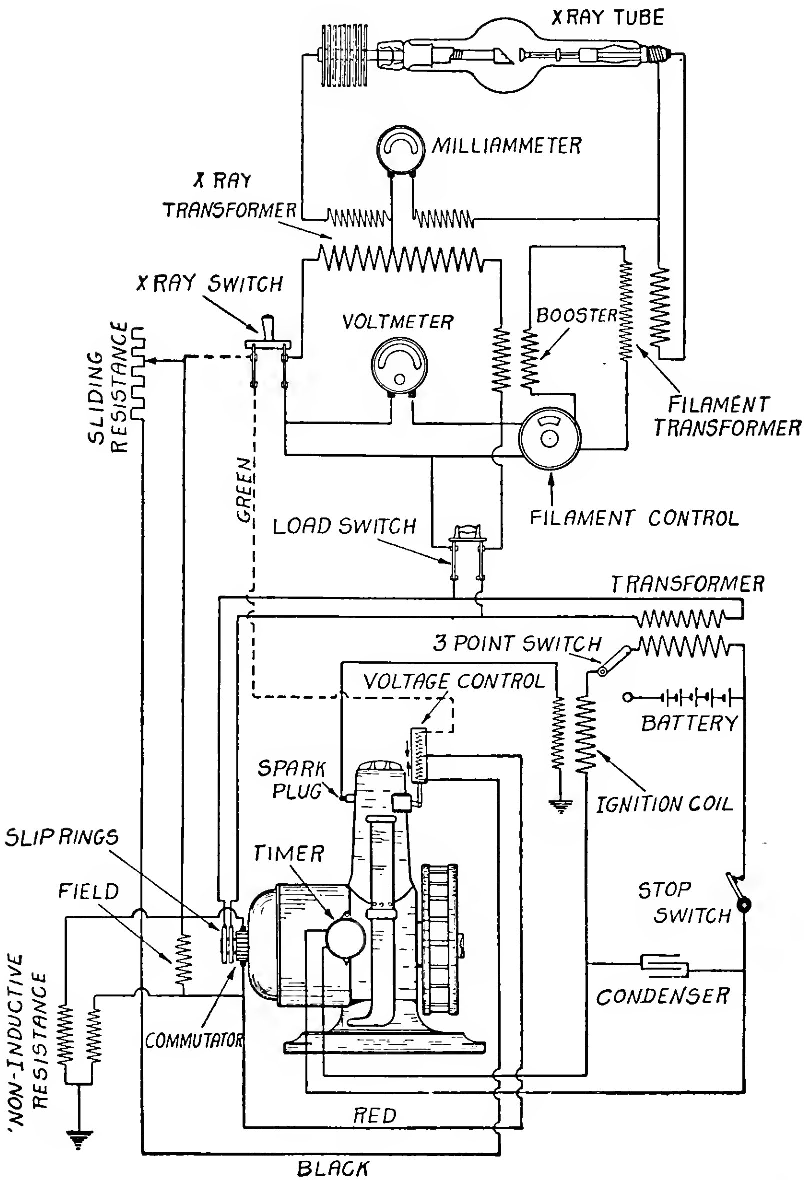

FIG. 73. Wiring diagram for United States Army portable x-ray unit. Dotted lines show connections for those machines having special control. In other cases these wires are omitted.

control circuit, changing the speed and thereby the voltage of the generator. The secondary circuit contains no rectifying device since the tube allows only each alternate half wave to pass. (See page 36 for a description of the tube.)

Fluoroscopic work is done at 5 ma. and all radiographic work at 10 ma. The maximum operating gap is about 5 inches, but may be reduced if desired by control of the machine speed.

Owing to the drop in line voltage upon closing the operating switch, it is necessary to secure a uniform filament current by inserting a "booster" in the primary circuits of the two transformers. This is merely a small transformer, which by carrying the main transformer primary current adds enough voltage to the filament transformer primary to compensate for the drop of voltage in the line.

Engine.*—The engine must be firmly fastened to a solid base by means of lag bolts or by some other convenient method. All fuel must be strained when filling tank, as impurities of any kind are certain to clog fuel pipes.

Use a good grade of medium oil and always make sure that the crank case is well filled before starting engine.

To start the engine, turn the fly-wheel rapidly by means of the crank, immediately remove crank and then press starting button and cut off air by means of lever on mixing valve body. When the engine has run for a few seconds, advance air adjustment lever to the point where the engine runs regularly and with the leanest possible mixture. A little practice will enable the operator to do this very quickly. This adjustment will vary with climatic conditions and the kind and grade of fuel used. It will be found to be slightly different when the engine has warmed up from what it was when the engine was started.

* See also "Delco" circular on model 9011, furnished by the manufacturer.

If the engine does not start, a few simple tests may determine the cause. Go carefully over all wiring and be sure that all electrical connections are tight and clean. Test to make sure that starting battery is not exhausted.

Examine the spark plug carefully and if the porcelain is broken or cracked, replace plug with a new one if possible. Hold the spark plug connecter about 1/8 inch away from spark plug terminal and turn fly-wheel over several times by means of the crank and see if a good spark is obtained in this manner. If not, the plug may be greasy or dirty; remove and clean thoroughly with gasoline and adjust the distance between the points to about 1/32 of an inch, or until a dime can be just passed between them.

Next, look at timer contacts to see that they are properly adjusted and are making good contact every time they close. If necessary, clean these contacts with a piece of fine sand paper. To adjust the distance between the points turn the engine over until the points open to their full extent. In this position a dime should just slip between the points. If necessary, adjust them by turning the contact screw in or out until the proper distance is obtained.

Next, examine commutator and brushes. The commutator may be dirty or greasy. It should never be allowed to remain in this condition, if the generator is to operate at maximum efficiency. Hold a piece of clean cloth soaked in a little kerosene against the commutator while the engine is running. Never use oil other than kerosene on commutator and always wipe dry with a piece of clean cloth afterwards. Examine brushes to see that they are in good condition and are making good contact.

To test your fuel line, fill the priming cup from a small oil can with gasoline, and crank. If the engine will run when using gasoline from the can, and will not run other-

wise, it indicates that fuel connections are loose or that the fuel hole in mixing valve body is clogged. Be sure there is no water in the gasoline tank. The fuel hole in mixing valve body or line may be cleaned out by blowing through it or by means of a fine wire. These few tests will usually locate the trouble. Now look at the cable leads which are all stamped with a corresponding number on the engine switch board. Be sure that they are properly connected to both engine and transformer unit. The amount of gasoline on *continuous* fluoroscopic work will be about 1 gallon per hour. On intermittent work, as is usually the actual case, a gallon will last about 3½ hours.

NOTE.—It may be noted that the wiring diagram as indicated for the portable unit has three wires to the voltage control, and that the x-ray switch has to open and close a circuit, on the left, through this coil and, on the right, through the x-ray transformer. This arrangement was made in order to speed up the engine promptly when put under load, but it has been found unnecessary. In some of the earlier machines, and perhaps in the later ones, this connection may be absent. When this is the case the wiring will be somewhat simpler, since the number of connections will be reduced and a slight change of design of the box may be possible.

The Transformer Unit.—The x-ray transformer unit contains the apparatus needed to transform and control the currents necessary for energizing the radiator type Coolidge tube used with these outfits. It consists of the following parts: (Figs. 74 and 75.)

The x-ray transformer (1) transforms the low tension alternating current from the gasoline engine generator unit into suitable high tension current.

The filament transformer (2) supplies the low tension current for heating the filament of the x-ray tube.

The booster transformer (3) keeps the filament of the x-ray tube constant.

The filament control (4) varies the amount of current

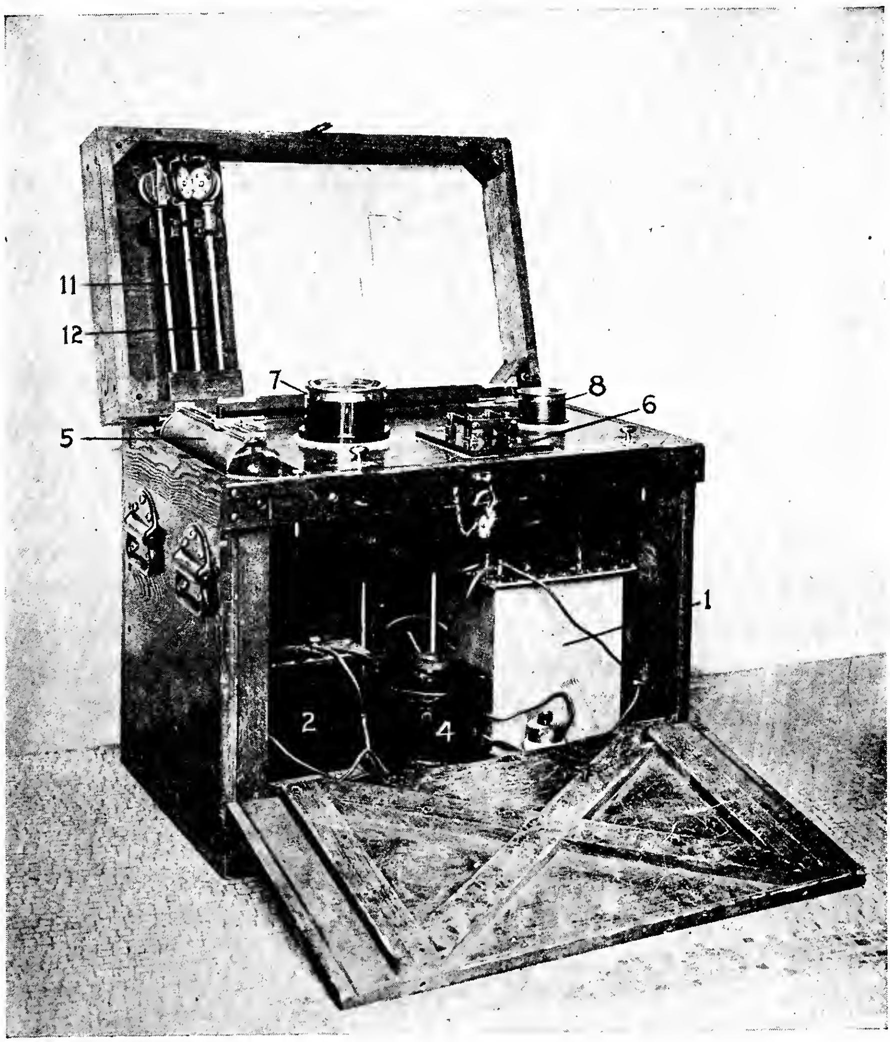

FIG. 74. Instrument box for portable unit, front view.

passing through the x-ray tube. A small knob will be found projecting from the side of this regulator—this is to open and close the circuit through the primary of the

filament transformer. When pushed in it is closed, as it should ordinarily remain.

The engine rheostat (5) serves as a means for controlling the speed of the gasoline engine. Moving the contact toward the front of the box increases the speed of the engine and thus raises the voltage of the generator.

The x-ray switch (6) opens or closes the circuit to the primary of the x-ray transformer and to the auxiliary throttle control.

The voltmeter (7) measures the voltage of the generator.

The milliammeter (8) measures the amount of current passing through the x-ray tube.

The main terminal board (9), whose five terminals project from rear side of the case, provides a means for connecting the x-ray transformer unit to the gasoline engine generator unit by means of the cable.

The pull switch terminal board (10) is, as the name indicates, for the purpose of attaching a pull switch to the apparatus. The split lugs at the end of the switch cable are to be inserted into the sockets in this terminal board to connect the pull switch in circuit. These connections put the pull switch in parallel with the x-ray switch and permit the closure of the circuit by either independent of the other.

After the engine and x-ray table are set up, place the x-ray transformer unit in position, *close* to the end of the table and so that the high tension outlets are equally spaced between the legs of the table. This is very important and should not be forgotten.

Unlock the box, raise the lid to an angle of about 45° from horizontal, and slide the cover of the box slowly to the left until the two hinge sections have been disengaged one from the other. The cover can now be removed from the box.

Pull out the two door bolts. The door in front can now be let down so that work can be done readily in the interior of the box. This door should be kept open at all times when the unit is in operation to avoid damage by corona, etc.

Push the split terminal lugs at one end of the cable into

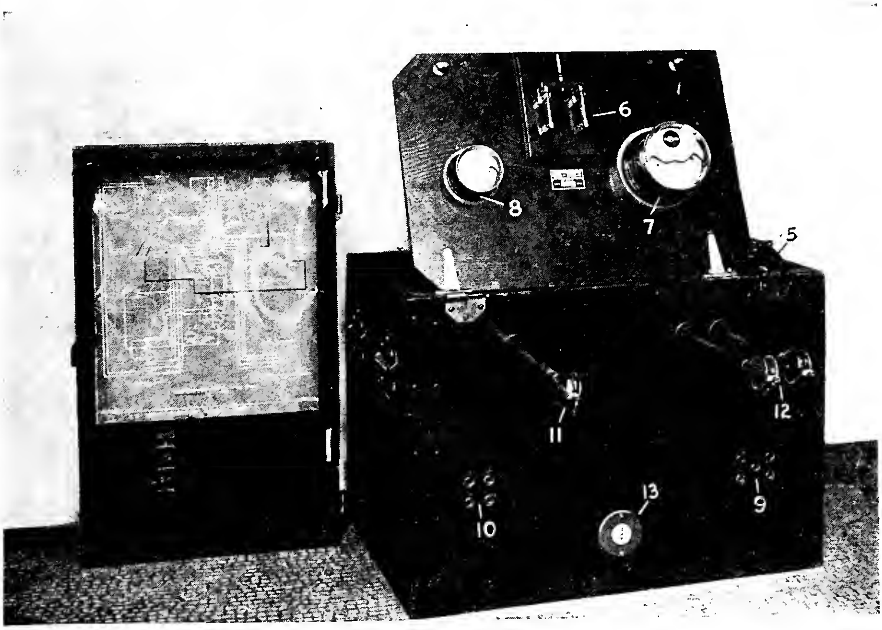

Fig. 75. Instrument box for portable unit showing instruments, high tension terminals, and openings for connections.

the sockets on main terminal board. These lugs are of different sizes so that they will only fit one way in the terminal board, and no mistake should be made. Connect the numbered lugs at the other end of the cable to the correspondingly marked connection posts on the switch board of the engine. Connect pull switch, if one is to be used, by inserting the split lugs on the switch cable in the sockets in the pull switch terminal board.

The high tension terminals (11) and (12) will be found

held in place in the cover by means of a clamp device. These terminals should be removed and screwed into the sockets.

These sockets and terminals are provided with different sized threads at their ends so that the terminals can only fit into their proper socket. The high tension terminal (11), provided with the spring hook terminal, screws into the single socket. The remaining terminals (12) can be screwed one into each of the remaining sockets.

Attach the cord from the positive terminal to the positive terminal of the tube box and the cords from the two negative terminals to the two binding posts on the negative terminal of the tube box.

Open the x-ray switch, the pull switch, and the line switch on the board of the engine; move the sliding contact of the engine-rheostat as close to the hinge side of the box as it will go. Start the engine and close the switch on the switch board of that unit. The filament of the tube should now be incandescent. Slowly move the contact on the engine rheostat toward the front of the box. The voltmeter should indicate higher and higher voltage. Continue until the voltmeter indicates about 160 volts.

For radiographic work, having adjusted the engine speed by means of the engine rheostat until the voltmeter reads 160 volts, set the filament control at 1.9, close the x-ray switch and readjust the engine rheostat and filament control until the milliammeter reads 10 ma., when the voltmeter should read from 110 to 115 volts.

Now open x-ray switch and read the voltage generated at no load, leaving the rheostat set in the 10 ma. position. Hereafter, whenever radiographic work is to be done, simply adjust the engine rheostat until the voltmeter indicates the voltage thus found.

To obtain the operating point for fluoroscopic work, viz.,

5 ma. at from 110 to 115 voltmeter reading, reduce the speed of the engine by means of the engine rheostat until the milliammeter indicates 5 ma. Upon examination of the voltmeter, it will be found to read from 110 to 115 volts. Open the x-ray switch and read the voltage generated at no load, leaving the engine rheostat set at 5 ma. point.

Hereafter, whenever fluoroscopic work is to be done, adjust the engine rheostat until the voltmeter again reads the voltage thus found.

In order to save fuel and wear and tear on the engine, it may be advisable to run the latter on reduced speed, except when making a radiograph, or during a fluoroscopic examination, or when it is desirable to use red room lamps designed for this unit. For this reason an adjustable stop is provided on the engine rheostat. This stop is set to bring the engine to proper speed for the work in hand, so that during the interval between making radiographs or fluoroscopic examinations, the engine speed can be reduced and reset for the next operation by merely running the contact against the adjustable stop.

This x-ray transformer unit should, as far as possible, be kept dry inside and out, and should be kept covered with a tarpaulin when not in use. Care should be taken to prevent sudden jarring and rough handling generally, to minimize the danger of putting meters, etc., out of adjustment.

The filament control must be adjusted carefully to give the proper current and primary voltage, and once adjusted it will stay fixed. Make sure the filament is lighted before throwing on power: this may easily be forgotten with an enclosed tube.

Should a spark pass in the secondary circuit when the operating switch is closed, it may be due to a temporary

surge. Unless an "arc" results, do not open the operating switch. Keep secondary wires well apart and well away from other objects to prevent corona and leakage. It is a good plan to connect the frame of the table to any convenient "ground."

Red Light for Fluoroscopic Room.—The generator may readily serve to give the reduced red light needed in fluoroscopic work. Fig. 76 shows how this is done; and either a

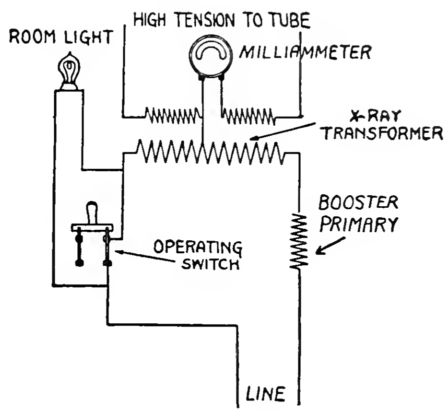

Fig. 76. Connections for red lamp over the fluoroscopic table, when used with portable unit.

high voltage ruby lamp or two 16 candle power, 110 volt ruby lamps in series are required. Do not connect in except as shown and do not attempt to load the generator up with additional lights or apparatus. Pulling the string switch alternates x-ray excitation and darkroom illumination. The extension cord and light connect onto the box at 13, Fig. 75.

Limitations.—This instrument will do the work for which it is designed, but must not be abused. Do not use the radiator type Coolidge tube on large installations or interrupterless transformers. It is not furnished for this purpose. It should only be used for radiographs at 10

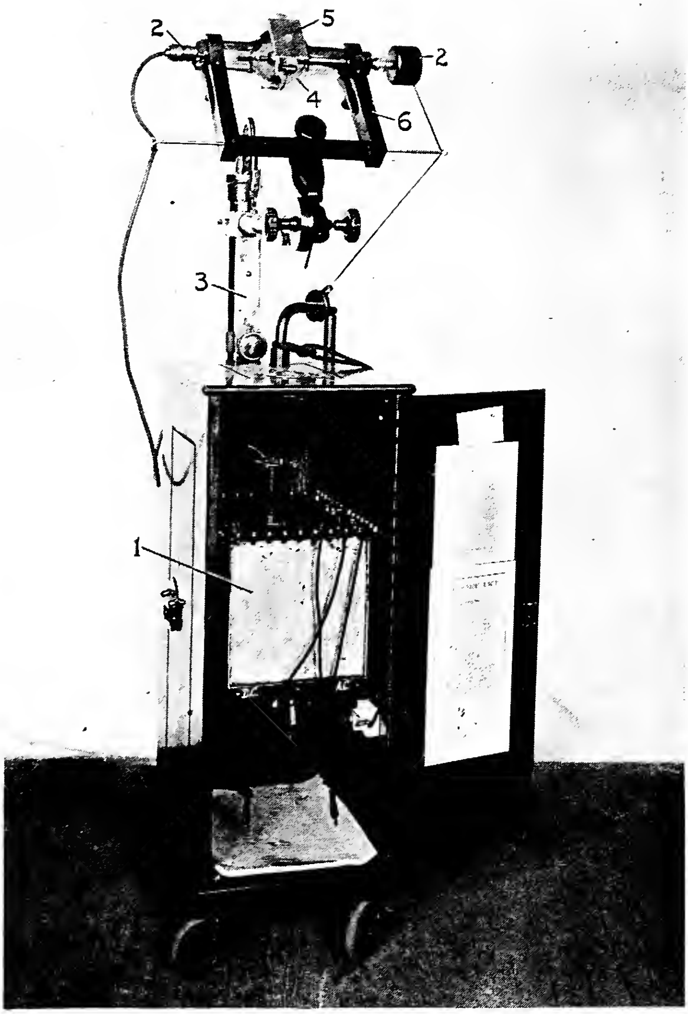

FIG. 77. United States Army bedside unit, complete for alternating current operation; double throw switch to be drawn to the right, loose connections below for rotary converter in using direct current.

ma. for a maximum exposure not exceeding 45 sec. with two minute intervals between. For fluoroscopic work it may be operated continuously, long enough for all practical necessities, at 5 ma. Do not attempt to use this tube at

other than these settings. Never attempt to operate the tube without the radiator.

The U. S. Army Bedside X-Ray Unit.—The unit shown in Fig. 77 was designed to permit x-ray examination in wards to be made with a *minimum* of disturbance of the patient. Many cases of fracture and other bone lesions, as well as various chest conditions, need such examinations. Pressure on the main x-ray outfit is often reduced and time saved by using such a unit.

This unit consists of a combined cabinet and tube stand, a radiator type Coolidge tube, special lead glass shield, and a transformer and control apparatus. The latter are enclosed in the cabinet.

Transformer.—The transformer (1) is designed to operate on alternating current of any ordinary frequency, if properly connected for the supply voltage available. Since the same primary circuit supplies power for both filament lighting and x-ray operation only one switch needs to be opened or closed.

Tube.—The radiator type of tube (2) with a special molded lead glass shield is used exclusively on these units. The tube will operate continuously with 5 ma. at a voltage sufficient for fluoroscopic work.

Tube Stand.—The tube stand (3) is counterbalanced and permits placing the tube in any desired position. It was made with a long horizontal extension to allow work over the top of a bed. The position of the tube during a fluoroscopic examination should be controlled by a properly trained assistant. See Fig. 78.

Limitation of Tube Current.—This outfit was not designed to permit variation by the operator of either current or voltage. The power limit was fixed by the usual fuse capacity of interior wiring for lighting purposes. More power would tend to blow fuses and thus interfere

with other uses of these circuits as well as delay the x-ray work. It gives a good average result when two conditions are met: (1) a tube current of 5 ma.; (2) a proper low tension voltage applied *to the transformer terminals.*

Service Conditions.—The user may find it necessary to operate on any one of the following supply systems.

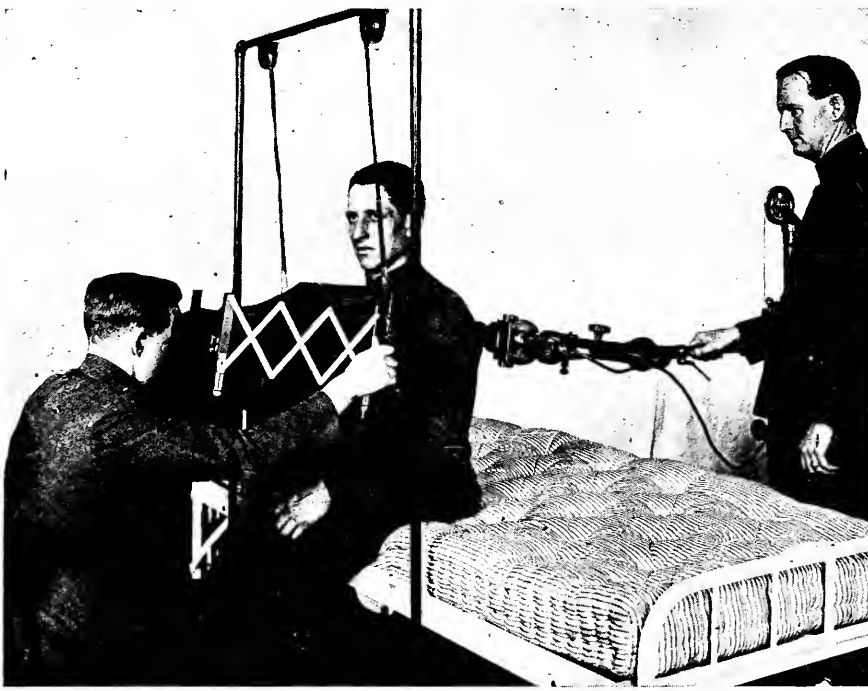

Fig. 78. Positions of parts when using the bedside unit with simple vertical fluoroscope for chest examination at the bedside.

1. 110 volt—alternating current.
2. 220 volt—alternating current.
3. 110 volt—direct current.
4. 220 volt—direct current.

Operation.—To operate this unit the first thing that it is absolutely necessary to know is whether alternating or direct current is supplied and at what voltage. Where any

question exists as to this point, no attempt should be made tc operate until all doubts are settled.

This unit will operate satisfactorily on 110 volt alternating current with no accessories. If the supply is 110 volt direct current, a rotary converter must be used, Fig. 79. This is connected by cables which will be found properly connected to the switch in the cabinet. Two leads are to

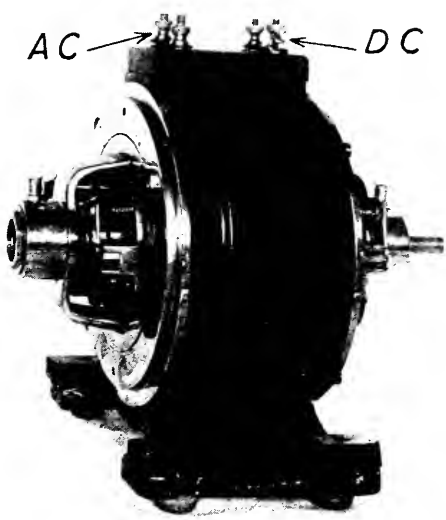

FIG. 79. Rotary converter used for direct current operation. U. S. Army bedside x-ray unit.

be connected to the binding posts on the rotary marked d.c., and the remaining two to the a.-c. terminals of the rotary. No mistake should be made, as these cables are plainly marked. On 220 volt, *direct* current, this unit may still be used, but a 220 volt rotary will be required. The rotary converter for 220 volts is mounted on a wooden base and has a suitable series resistance. This rotary is designed and adjusted to give 110 volts a.c. at the collector rings under load.

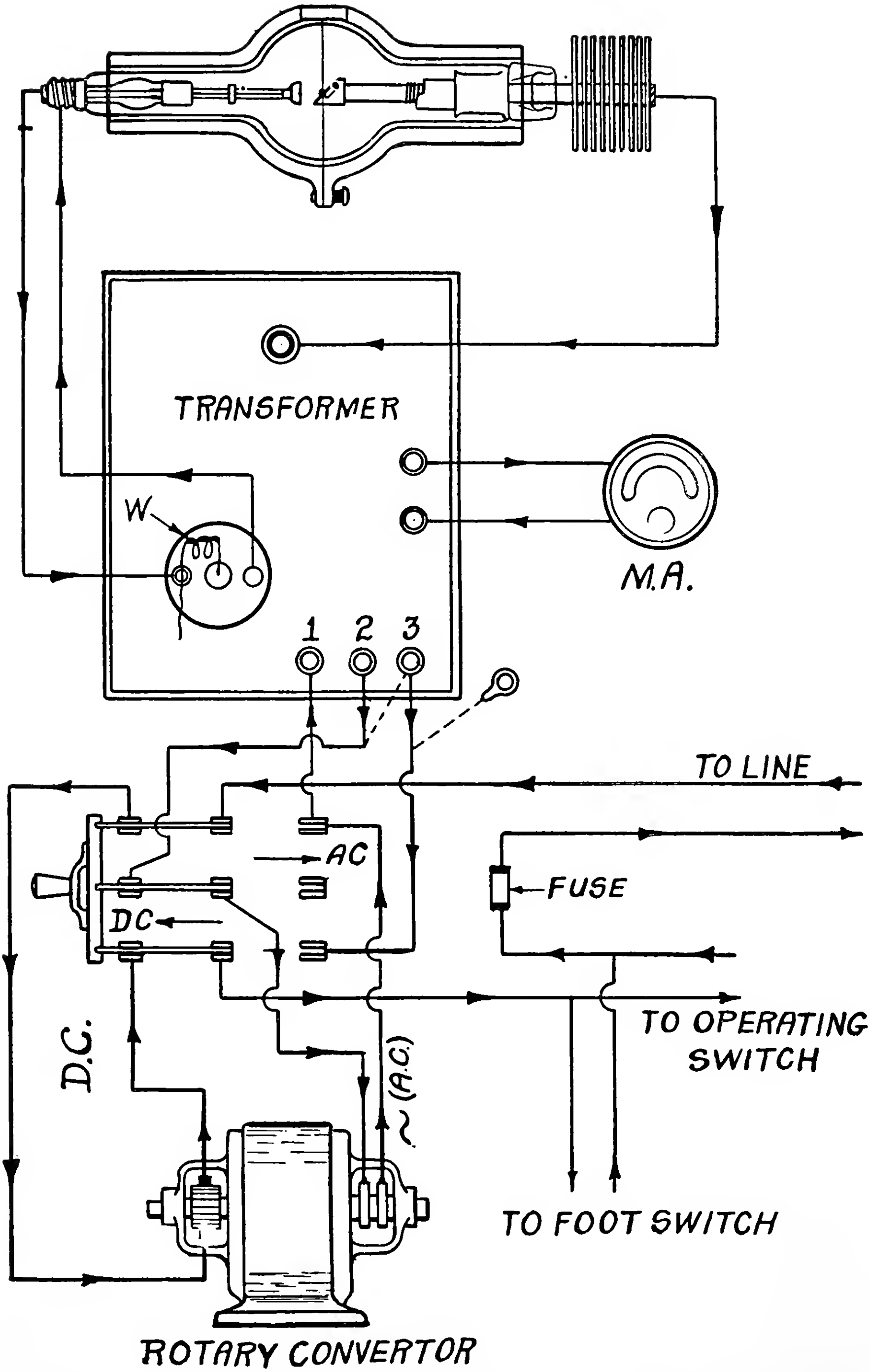

FIG. 80. Wiring diagram for connections, United States Army bedside unit for 110-220 volt, d.c. or 110 volt a.c.

X-Ray Transformer.—The x-ray transformer has three binding posts numbered 1, 2, and 3. One and three are used in *all cases except* for 110 volt direct-current operation, for which numbers 1 and 2 are used.

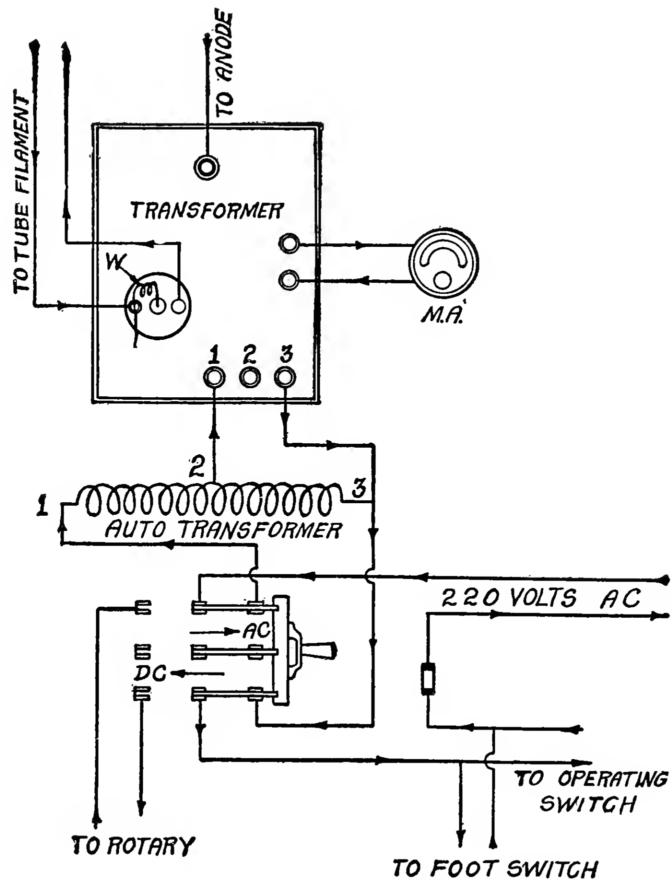

FIG. 81. Wiring diagram for connections, United States Army bedside unit for 220 volts a.-c. circuit.

When the wire is removed from part three it should be taped so as not to make an accidental contact. Fig. 80 shows in full lines the connection for 110 volt d.c., 220 d.c. and 110 a.c. The switch must be closed on d.c. for both direct-current volt-

ages, and on the a.c. side for both voltages of alternating current.

If the current is 220 alternating a special autotransformer is required. The one that is supplied has three wires marked 1, 2, and 3. To connect up for this voltage (Fig. 81) transfer the line wires to terminals 1 and 3 of the autotransformer and connect 1 of the x-ray transformer to 2 of the autotransformer and 3 of the x-ray transformer to 3 of autotransformer.

Tube.—The radiator type Coolidge tube will be used exclusively on these outfits and little or no adjustment can or will be left to the operator. This tube does not require a rectifier of any description and will safely carry 5 ma. for an indefinite time. For radiographic work it is advisable to use intensifying screens.

To Adjust the Tube—

1. Remove radiator after loosening screw at the end.
2. Carefully place the two halves of the lead glass shield (4) over the tube and fasten together by means of the screws. Do not turn screws tight or a broken shield is sure to result.
3. Turn the tube so that the center of the target is in line with the opening in the shield (5).
4. Push the cork wedges, which are supplied, in around the target end of tube first, then in around cathode end so as to hold tube firmly in this position. Replace radiator. If this screw does not turn easily, hold the tube by the radiator and *not* by the glass. Never attempt to operate this tube without the radiator in place.

When placing the tube in the holder be sure that the shield containing the tube is clamped in the holder (6) and *not* the tube ends. To adjust the aluminum filter, which it is necessary to use at all times, loosen the two screws that hold the shield together each side of the opening, place the

aluminum filter in position and retighten screws, always remembering that glass will break if fastened too tight. The diaphragm with the round hole will cover an area 5 inches in diameter at 20 inches target-screen distance, and the square opening an area 14 inches square at the same target-screen distance. A strip of lead foil may be attached by adhesive tape over the crack between the two halves of the lead glass shield.

After everything else is ready connect with your source of current and make sure that you throw the two-way switch to the correct side. Both ends are marked and there can be no excuse for not doing this right. After throwing this switch, watch the milliammeter. If it goes to more than 5 ma., adjust the resistance wire on the top of the terminal inside the cabinet, increasing the amount included between binding posts; if less than 5 ma., reduce the amount so included until the milliammeter reads between 4½ and 5 ma.

This apparatus, operated as directed, will do the work for which it was designed. The operator should not attempt any adjustments other than those described. All others have been attended to by the designers and makers. It is intended that intensifying screens should be used with this unit for all radiographic work, unless immobilization is easily accomplished.

Care in Moving.—The tube holder permits of placing the tube as shown in Fig. 77, so that when moving in a ward there is less danger of collision between the tube and other objects. Always move carefully as the tube is fragile. When the holder is extended the cabinet is less stable, and even more care must be taken. When moving up or down stairs always remove the tube and clamp.

Exposure.—The exposure required with this outfit will depend on conditions as to film or plate, and on whether

an intensifying screen is used and its speed. If one is accustomed to using 40 ma. at about a 5-inch gap, with the same conditions as to distance and plate or film, the time of exposure is to be multiplied by eight. Using an intensifying screen will reduce this exposure an amount depending on the multiplying power of the screen used. A good screen will reduce the exposure time to from 1/10 to 1/15 of that required with no screen, when a plate or a single-coated film is used.

If a double-coated film is supplied, the time without screens is reduced to ½. For double-coated film and single screen, the time is further reduced, under good conditions, to about 1/25 or 1/30 of that for single coating and no screen.

An excellent chest negative of a man of average size has been made with the following settings:

Target-plate distance—28 inches.

Current—5 ma.

Eastman double-coated film.

Edwards screen (single).

Exposure time—1 sec.

A little care and practice will enable one to do a large amount of work at a minimum of disturbance or discomfort to the patient and with quite reasonable exposure times.

Accessory Apparatus.—Hand fluoroscope 5 x 7, the usual type for examination of extremities.

Fluoroscope for chest examination with special support. See Fig. 78. This can be folded and disassembled for moving from place to place.

Reducing goggles are furnished to enable the operator to find his way around a lighted room and then proceed at once to do reasonably good fluoroscopic work. These contain a red and a green celluloid disc; for a fairly dark

room the red alone may serve, for a brightly lighted room both are inserted. Just before bringing the fluoroscope in position, close the eyes, raise the goggles to rest on the forehead, and open the eyes only after the fluoroscope is in position. Reverse these steps when the examination is completed.

Fluoroscopic Unit.—For the most successful and convenient fluoroscopy the operator should have control over both screen brightness and the penetration of the rays. A unit embodying these control features and of correct capacity for operation with the self-rectifying Coolidge tube has been devised and is in limited use in connection with the horizontal and vertical fluoroscope, although not officially adopted and regularly supplied by the government. The transformer is about the same size as that used in the bedside unit but differs in having entirely separate high tension and filament transformers in the same case, rather than two secondary windings energized by the same primary as has the bedside unit. The primary of the high tension transformer and the primary of the Coolidge filament transformer may be separately controlled by turning two knobs on the control cabinet, giving various tube currents and voltages with a much simpler adjustment than heretofore in use.

This unit serves, in those instances where it is installed, to remove the fluoroscopic work from the large standard machine and thereby increase the capacity of the x-ray room without the addition of another high power outfit. It can be run from 110 volts a.c., from 220 volts a.c. by means of a small autotransformer, or from 110 or 220 volts d.c. with a suitable rotary converter. A wiring diagram is supplied with the machine.

STANDARD POSITIONS

It has been the endeavor, in the following series of photographic reproductions of the various parts of the body, to illustrate what seem the simplest and most reliable methods of securing x-ray plates of these various parts, which are of most value in determining both the normal and the pathological structure.

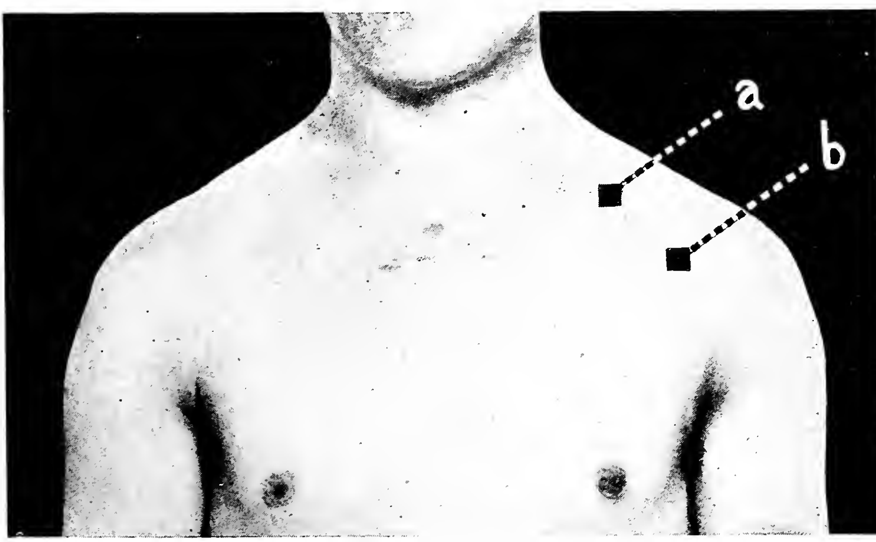

FIG. 82. Position: (a) clavicle (b) shoulder joint.

The necessity for a thorough knowledge of normal x-ray shadows is too apparent to need further discussion here. No amount of study and observation of pathological or abnormal conditions will be of value unless the individual has first acquired a true concept of the normal. In order

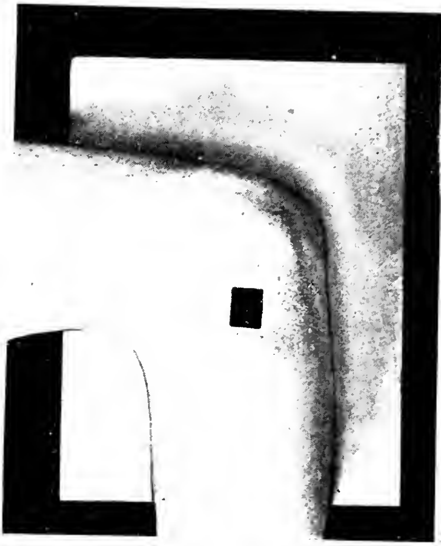

FIG. 83. Elbow, lateral view.

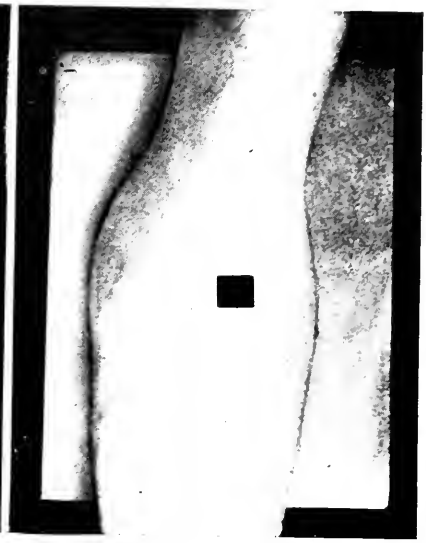

FIG. 84. Elbow, anteroposterior view.

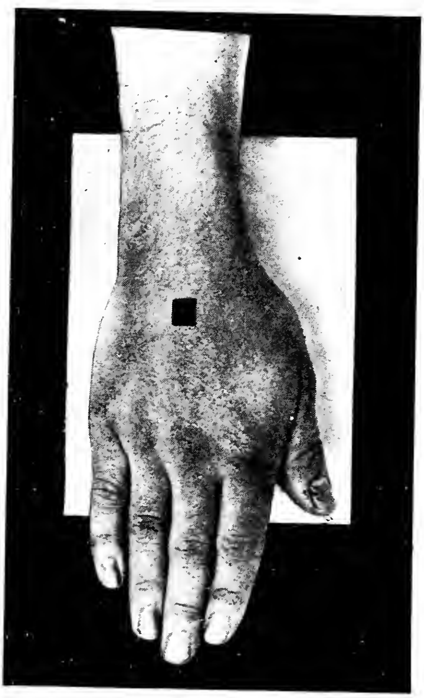

FIG. 85. Wrist, anteroposterior view.

FIG. 86. Wrist, lateral view.

to obtain such a concept some method must be followed which will give the least amount of variation in the apparent size, shape, and relation of the parts examined when attempting to reproduce the same results in the same or different patients. This is essentially the funda-

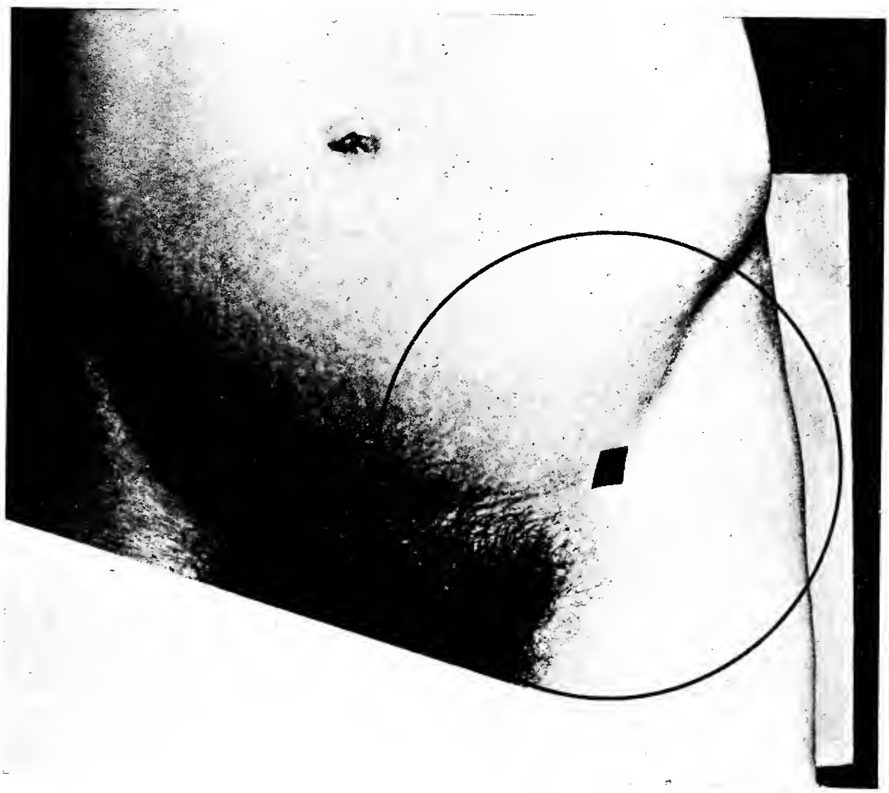

FIG. 87. Hip joint, anteroposterior view.

mental principle of all x-ray interpretation. It has been found by roentgenologists that this can only be accomplished by establishing standard relations between the source of the rays, the sensitive plate and the part to be examined. This is what is meant when speaking of the standard positions for the different parts of the body. It must be constantly borne in mind that even a slight change

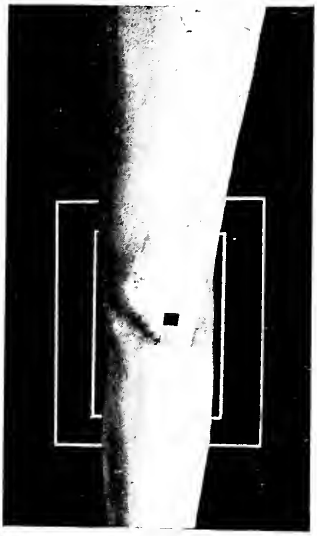

FIG. 88. Knee, antero-posterior view.

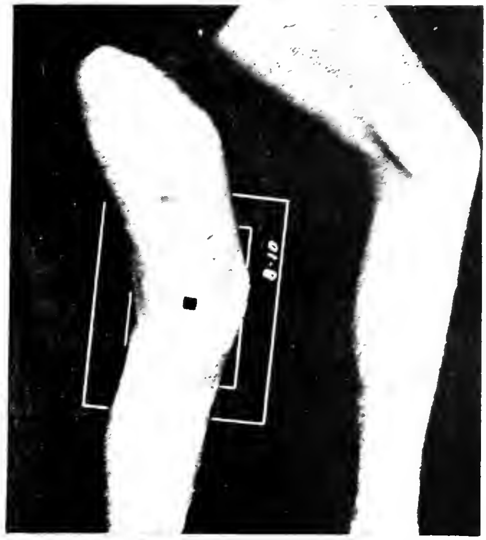

FIG. 89. Knee, lateral view.

FIG. 90. Ankle, antero-posterior view.

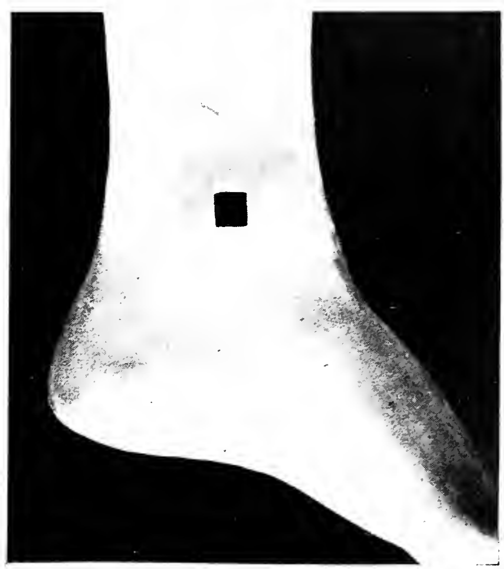

FIG. 91. Ankle, lateral view (marker over internal malleolus).

FIG. 92

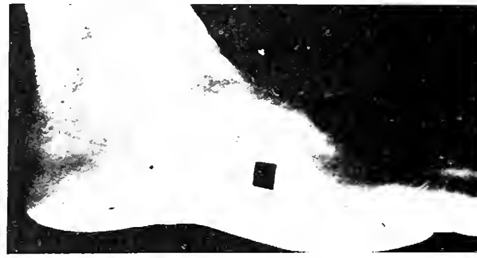

FIG. 93

FIG. 92. Foot, anteroposterior view.

FIG. 93. Foot, lateral view, marker over first metatarsal.

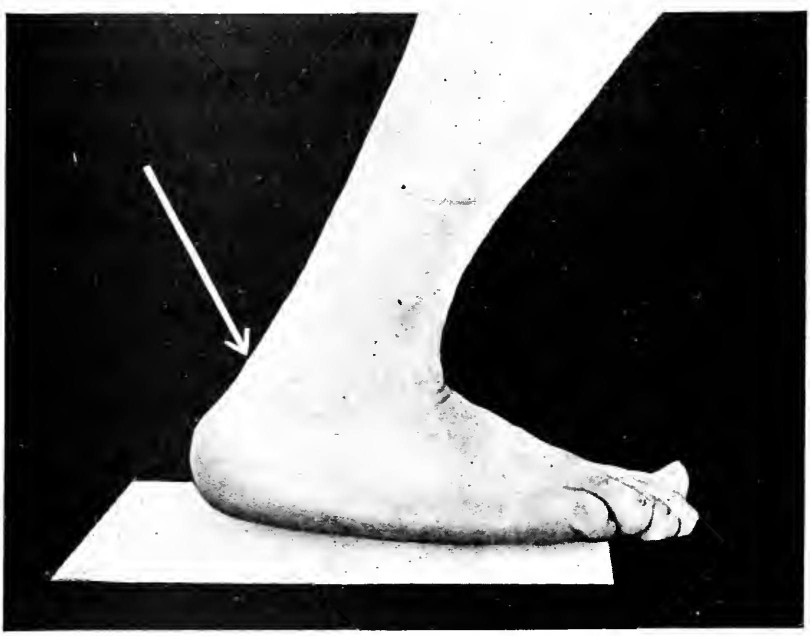

FIG. 94. Position for demonstration of the posterior portion of os calcis; arrow indicates the direction of the rays.

in the relative positions of the target, plate, and part may result in some distortion which might render the plate of doubtful value in any endeavor to determine the abnormal by its comparison with the normal. While experience has shown that the best results are obtained by adhering to these positions, it must be remembered that often they must be modified to meet the need of individual cases.

Several illustrations of standard positions which are not shown elsewhere in the manual are here grouped together.

These are the only parts of the body which the x-ray manipulator should be allowed to examine. All other examinations require the personal attention of the roentgenologist.

DANGERS AND PROTECTION

Dangers from the X-Rays.—The danger to the skin of operator and patient requires careful consideration in order to avoid serious injury. It is customary to speak of a dose that will cause a slight temporary redness of the skin as an erythema dose. This dose undoubtedly varies considerably according to the age of the patient and to the judgment of the observer as to the extent of redness which may be called "slight."

The skin dose will depend on the following factors:

1. Target-skin distance.
2. Spark gap (voltage).
3. Current through the tube.
4. Time or duration of exposure.
5. Nature and thickness of filter used.

While complete agreement as to what will give an erythema dose can hardly be expected, all will agree that the dose will increase with the duration of exposure, with the current and with the spark gap; and will decrease as distance between target and skin is increased and as thicker filters are used.

It is convenient in this connection to combine the tube current in ma. and the time in minutes, and speak of milliampere minutes, but it *must be clearly understood that the number of milliampere minutes allowable varies with the spark gap.*

Working at a target-skin distance of 20 inches and a 5-inch gap, 45 milliampere minutes may be safely allowed

if no filter is used. For general safety, a filter of 1 mm. of aluminum is advised, and then an increase of about 40 per cent may be allowed—or about 60 ma. minutes may be taken as a safe total to be received by the skin at this gap and target-skin distance. Thus, at 5 ma.—5-inch gap—20 inches—1 mm. al., a total of twelve minutes may be used on one skin area for fluoroscopic examination, *if no radiograph is to be taken.*

If 20 ma. minutes at a 5-inch gap were used in fluoroscopy there remains only 40 ma. minutes for radiographic work. If 40 ma. is used and 10 seconds is required for a negative, only 6 plates could be safely made. On this account it is wise to make fluoroscopic examinations as brief as is consistent with good work and to use intensifying screens in serial radiography.

A very important point to remember is that when using a smaller gap, although the amount of radiation reaching the skin is less for the same current, the exposure required in radiographic work is very much longer. To get the same plate density at lower gaps, the skin risk is greater. Many cases of dermatitis are due to prolonged or repeated exposure with too small a back-up gap for the work in hand.

Be sure that unfiltered rays along the axis of the tube, which do not have to pass through the lead glass bowl, do not reach the patient.

When an erythema dose is reached or approached, an interval of three weeks should elapse before again exposing.

Exposure beyond an erythema dose may be justified when circumstances arise of an unusual nature. But the surgeon or attending physician should be warned by the roentgenologist before such a risk is to be taken.

Protection of the Operator from the X-Rays.—The ele-

ment of increase in the work time makes care in the protection of the operator of extreme importance. Two things are clear in this matter: First, that effects are cumulative; second, that evidence of injury may develop late. Since the demands of the art fix the amount of radiation for specific purposes, the operator can do only three things for self-protection.

1. Increase the distance from the target to any part of his body.

2. Interpose absorbing material between himself and the tube.

3. Reduce the time devoted to the work.

The first of these is applicable in radiographic work only, as in fluoroscopy he must work at close range. The third can have only limited application in a military hospital during war, so the second is the practical method.

The following suggestions are offered in the hope that they may be applied:

1. That in all radiographic and treatment work no direct rays be allowed to reach the operator's body without passing through at least 1/16 inch of lead where lead can be used. Lead glass should have an absorption equivalent to 1/32 inch of lead.

2. That in addition to this lead protection, the operator keep several feet from the tube in treatment and heavy radiography.

3. That in using either a vertical or a horizontal fluoroscope, a careful test be made to ensure that no direct rays come through bad joints, holes in lead, or other unprotected openings.

4. That the fluoroscopic screen be protected with lead glass at least equivalent to 1/32 inch of lead.

5. That the lead glass and sheet lead on the frame overlap at least ¼ inch.

6. That the diaphragm never be opened or moved so as to send part of the beam past the screen, and 1 mm. of aluminum be used as a filter in all cases.

7. That in horizontal fluoroscopy some protection be given for rays scattered at right angles to the patient's body.

8. That the operator study his working conditions so as to secure the results required in the minimum time.

Under no circumstances should an operator use any part of his body for fluoroscopic demonstration, nor should he hold any plate or dental film in position during exposure.

It should be understood that the final responsibility for protection, both of the patient and the operator, rests on the roentgenologist himself, and after his apparatus is installed he should not neglect to test for gross leaks and insufficient protection.

The fluoroscopic screen in a well-darkened room will help to find where danger may lurk but gives no idea of the amount of radiation involved in the indicated directions.

According to the work of Pfahler and others, on a 5-inch gap the number of milliampere-minutes required with unfiltered radiation for a full erythema dose at 20 inches, allowing no factor of safety, will be about 60. This means that without filter, 5 ma., at a 5-inch gap, 20 inches target-skin distance, 12 minutes will almost certainly give a skin inflammation.

A test of the danger may be made as follows: take a few dental films, number them, and place in the position occupied by the operator's body when at work, but attached to his clothing. After he has worked for some time, develop these films and note their general density.

Then using the above data, 5 ma. at 20-inch target-plate distance and a 5-inch gap, expose a series of films for defi-

nite fractions of the time required for an erythema dose. These fractions must be small and care must be taken to develop these films exactly as the test films were developed. In this way it is possible to determine the time the operator must work to approximate an erythema dose. Probably ½ such a dose per month would not have any serious effect.

Electrical Dangers.—In the use of high-power x-ray apparatus, care must be taken to avoid discharge from high tension lines to earth through the body of either patient or operator. Fatal results may follow, and in any event the nervous shock to the patient may be serious. Danger arises from sparks followed by an arc discharge from the high voltage line to the body, thence to earth.

To get such a discharge, we must have:

1. Grounding of patient or contact with badly insulated grounding material.

2. So short an air distance from some part of the high tension system as will allow a break over spark.

A single spark, while disconcerting, is not dangerous to life, but it serves to pave the way for a heavy *discharge from the line* if the supply is maintained. On static machines and most induction coils, body connection so reduces the line voltage as to preclude any fatal amount of current; but with the modern high power transformer it is a different matter.

The danger of an initial spark-over to the body is solely a matter of line to skin distance and voltage from line to earth. When a tube is taking current, the voltage from either line to earth is less than it would be on the same control setting if no current were passing. Hence, failure of the tube to take current at any time tends to cause discharge to the patient. The following are the common ways in which this may happen:

1. Failure to complete high tension connection.
2. "Cranky" gas-tube.
3. Failure to light Coolidge filament before turning on high tension.
4. Break or disconnection of Coolidge filament circuit while running.
5. Attempting to pass current through Coolidge tube in wrong direction.

Another cause for spark-over is the high tension surge often caused on closing the primary switch of the transformer.

Keep all high tension lines at least twice as far from any portion of the patient as the working spark gap. Thus, if using an equivalent gap of 6 inches, allow no wire closer than 12 inches. A grounded metal or conducting screen *between* the high tension lines and the patient is complete protection for the patient; thus, a horizontal fluoroscope with a grounded frame is safe with the tube below; but when the patient is between the high tension line and a grounded metal or conducting table, danger is greatly increased.

Type of Control.—Much has been said of the relative danger with various controls. Simply stated it amounts to this: the rise in voltage when the tube fails to take current is very much greater on a resistance control (See Figs. 19 and 20), so that the chance of an initial spark is greater; but after such a spark, the chance of a following arc is reduced by reason of resistance in the primary circuit.

With autotransformer control, or operation without resistance—i. e., with rheostat all out—the rise in voltage on open circuit is less; but if an arc *is* started, it is very dangerous. A quick-acting, over-load primary break is very desirable.

Resuscitation from Electric Shock or Asphyxiation.—The prone pressure method of artificial respiration, devised by Prof. Schaefer, of Edinburgh, has been advocated as the most effective method by the United States Bureau of Mines' Committee. This method can be used with oxygen inhalator. It should always be used immediately to resuscitate asphyxiated persons and kept up continuously until approved mechanical resuscitating devices are

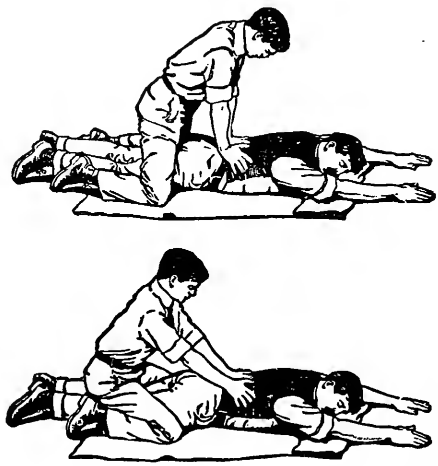

Fig. 95. Resuscitation from electric shock.
Above—Expiration, pressure on. Below—Inspiration, pressure off.

brought to the scene and adjusted on the patient. Heart stimulant should be given as frequently as necessary.

This system can be used in cases of electric shock, after the victim has been removed from the live conductor, in cases of gas poisoning or asphyxiation from any cause. *Artificial respiration should be begun promptly, as life persists only a few minutes after breathing stops.*

Quickly feel with your finger in the victim's mouth and throat and remove any foreign body (tobacco, false teeth, etc.), then begin artificial respiration at once. Do not stop to loosen patient's clothing; every moment is precious.

Lay the subject on his belly, with arms extended as straight forward as possible, and with face to one side, so that the nose and mouth are free for breathing. Draw forward the subject's tongue.

Do not permit bystanders to crowd around and shut off the air.

Kneel, straddling the subject's thighs and facing his head; rest the palms of your hands on the loins with thumbs nearly touching and with fingers spread over the lower ribs. Fig. 95.

With arms held straight, swing forward slowly, so that the weight of your body is gradually brought to bear upon the subject. This operation, which should take two or three seconds, must not be violent, lest internal organs be injured. The air is thus forced out of the lungs.

Now immediately swing backward so as to remove the pressure, but leave your hands in place. The air thus enters the lungs.

After two seconds swing forward again, repeating this operation twelve to fifteen times to a minute, a complete respiration every four or five seconds. While this is being done, an assistant should loosen any tight clothing about subject's neck, chest or waist.

Continue artificial respiration (if necessary) two hours or longer, without interruption, until natural breathing is restored. Even when natural breathing begins, carefully watch that it continues. If it stops, begin artificial respiration again.

Keep subject warm by applying a proper covering or artificial heat, hot water bags, etc.

Do not give stimulants or liquids by mouth until subject is fully conscious.

Strive for Imaging Excellence

Motto of the United States Army X-Ray Specialist Course

Between January, 1984 and January, 1987, I was fortunate to serve in the United States Army in the capacity of Chief of the X-Ray Branch and Program Director for the United States Army X-Ray Specialist Course at the Academy of the Health Sciences, Fort Sam Houston, Texas. As a Medical Service Corps officer with the rank of Captain, I was faced with the sobering responsibility of leading approximately 30 x-ray instructors in the largest medical radiography training mission in the free world. One of my major goals was to analyze the existing curriculum and generate valid recommendations for educational improvements to my military superiors.

After developing goals and hypotheses concerning the curricular variables in question and after defining assumptions, limitations, and research methods, I conducted a review of the available research and literature on the subject of radiography education in the United States Army. Aside from the X-Ray Branch documents, that went back about 10 years, there was virtually no readily available information about the origin of the Army radiography educational mission or its clinical mission.

Continuing the search, I learned of the first use of x-rays by the Army during the Spanish American War of 1898 and that the beginning of America's involvement in World War I during 1917 marked the first formalization of radiography training in the Army on a tremendously large scale. Within approximately one year, the United States Army medical department set up three training centers at the U.S. Army Medical School in Washington, D.C., Fort Riley,

Kansas, and Camp Greenleaf, Georgia. After the close of the Fort Riley school, the majority of Army X-Ray Manipulators, as they were called, were trained at Camp Greenleaf. For each officer—roentgenologist (physician) trained, there were two x-ray manipulators. At one time, Camp Greenleaf had plans to generate 120 military roentgenologists. Considering that the U.S. Army Medical School at one time generated 150 x-ray manipulators per month, one may safely conclude that several thousand U.S. Army x-ray manipulators must have been trained for duty during World War I.

Developing significant interest in WWI Army Radiography, I searched extensively for the infamous textbook developed during this period for training the Army x-ray manipulator towards the close of the war. It's title was, *The United States Army X-Ray Manual*. If I could get my hands on this textbook. I knew I would have a glimpse into the past that few have ever attained in radiography education . As my library search went out, I happened to locate one, However, I was only able to keep it for a couple of days absorbing as much as I could. Upon returning it to the library, I thought that some old bookstore would surely know where I could find a copy of the Manual for my personal library. Searching and calling on old bookstores that catered to the antique book market, I was unable to locate the Manual. However, I did follow up on one of the greatest tips in my life.

Calling this one bookstore, the owner said that I should try to find a person named George Miller who was supposedly trained as an Army radiographer. Searching the telephone directory, I came upon his name and address. I called Mr. Miller that same day, the Fourth of July, 1985. George told me to come over, and that he had the book. When I got there, I was completely dumbfounded when he not only enlightened me on his extraordinary military career spanning some 30 years, but when he handed me two books and said, "Here, I won't be needing these. You can have them." The two books were, *The United States Army X-Ray Manual* and the *Extract from the United States Army X-Ray Manual*.

Mr. Miller explained to me that when he trained as an Army radiographer in 1932, the *Extract* was given to the enlisted personnel who were training to be x-ray technicians and the *Manual*

was given to the doctors who were training to become miliary roentgenologists. I never expected to receive such a gift from Mr. Miller. Through meeting him, I have been extremely blessed with some incredible knowledge concerning the role of the radiographer in the United States Army. And, George and I have become genuine friends. Mr. Miller retired at the rank of Master Sergeant in the early 1950s. At one time he served as the Non-commissioned Officer in Charge of the X-Ray Branch when all of the formal radiography training centered at Fort Sam Houston, Texas immediately after World War II.

After completing the assessment on the Army radiography curriculum and taking stock of a training process that spans this entire century, I realized that the *Extract* that Mr. Miller gave me was one of the first, if not *the* first, educational textbook produced for the training of radiographers in North America. Later, I would learn that Chapter 1, entitled "X-Ray Physics" was written by Lieutenant Colonel John Sanford Shearer, Ph.D. This physicist taught at Cornell University and published extensively between 1897 and 1922 on the various aspects of the physical foundations of radiography. His insight and tremendous intensity of concern for the training of American radiographers and roentgenologists was ten years before Ed C. Jerman's contributions to the field.

The Extract that you now hold is a real treasure for those who have a sense of history about radiography. Show it to your colleagues and marvel at the x-ray technology of World War I and how, even though things look outdated, many things have not really changed. Show it to the new students in medical imaging and let them begin to sense an appreciation of the present medical imaging technology. Remember, also, that although the origination of this historical document began with those scientists and physician-roentgenologists of the WWI period whose roentgenology requirements gave birth to the Army x-ray manipulators, it was Master Sergeant (Retired) George Miller, who kept this rare edition all these years so that we all could enjoy a tremendous radiography flashback.

Thanks George, on behalf of all American radiographers.

Finally, if you are seeking to know much more about the Army radiography evolution between 1917 and 1946, please consult three

articles that were published in *Radiologic Technology* in 1985, 1986, and 1987. If you would like to know the results of the assessment of the Army radiography curriculum that I conducted between 1984 and 1987, write to The Burnell Company/Publishers, Inc., for a copy of my findings. If you would like first-hand knowledge and experience about what it is like being a genuine Army radiographer, I know an educational program with a long and proud tradition of training. In today's Army you can be all that you can be and then some. You can learn how to "Strive for Imaging Excellence" at the Army radiography program, Fort Sam Houston, Texas.

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